The Journal of Bone and Joint Surgery

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The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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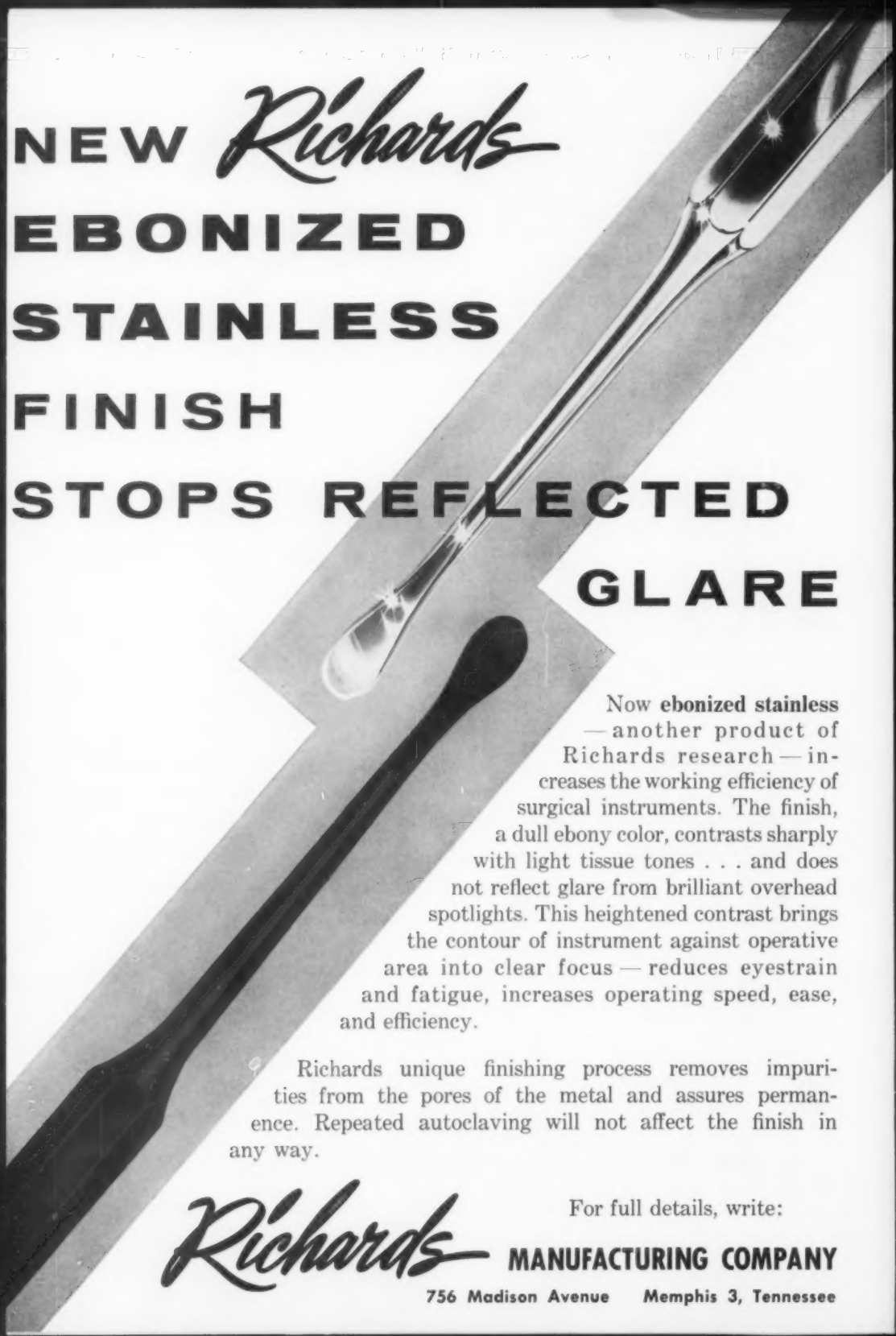

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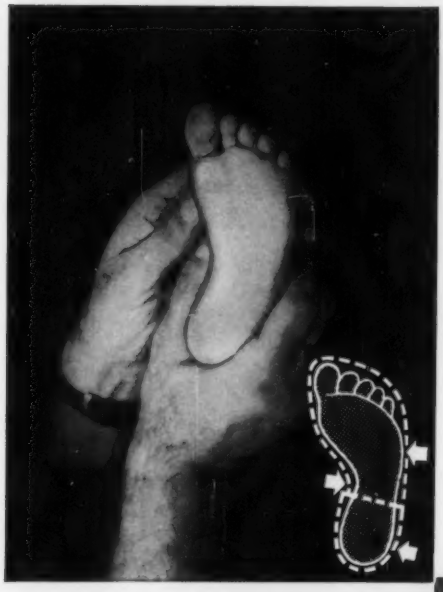

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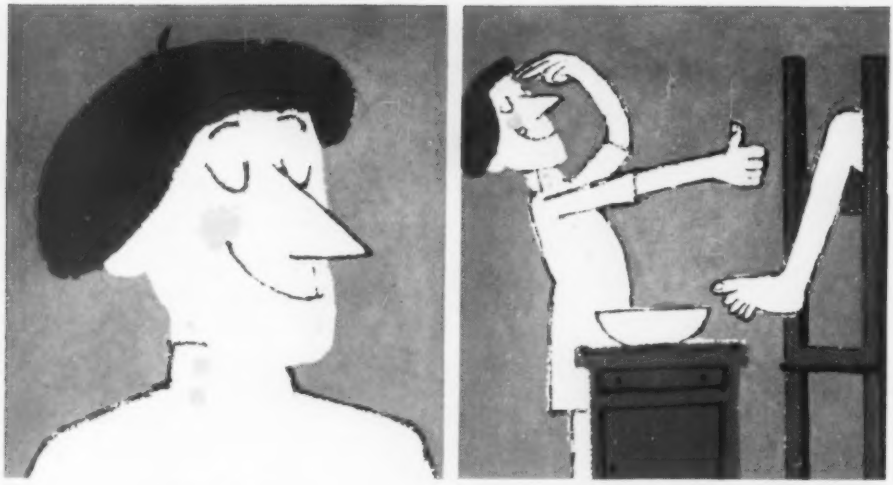

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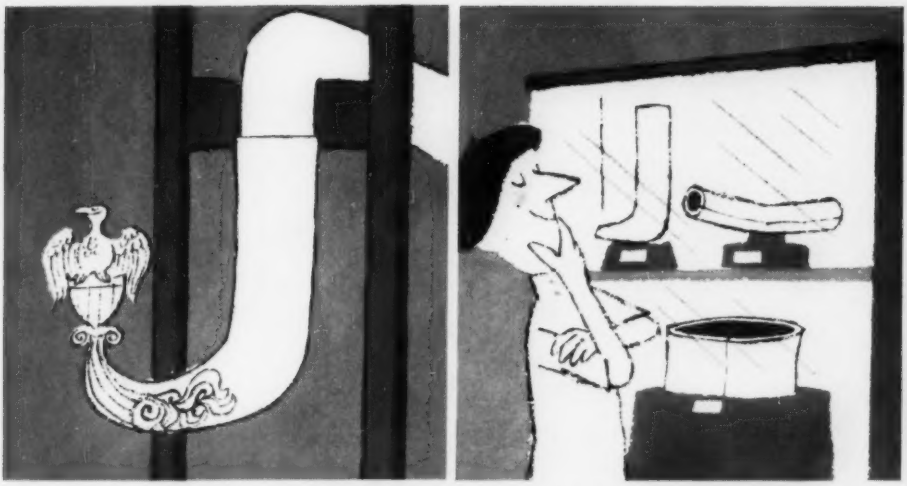

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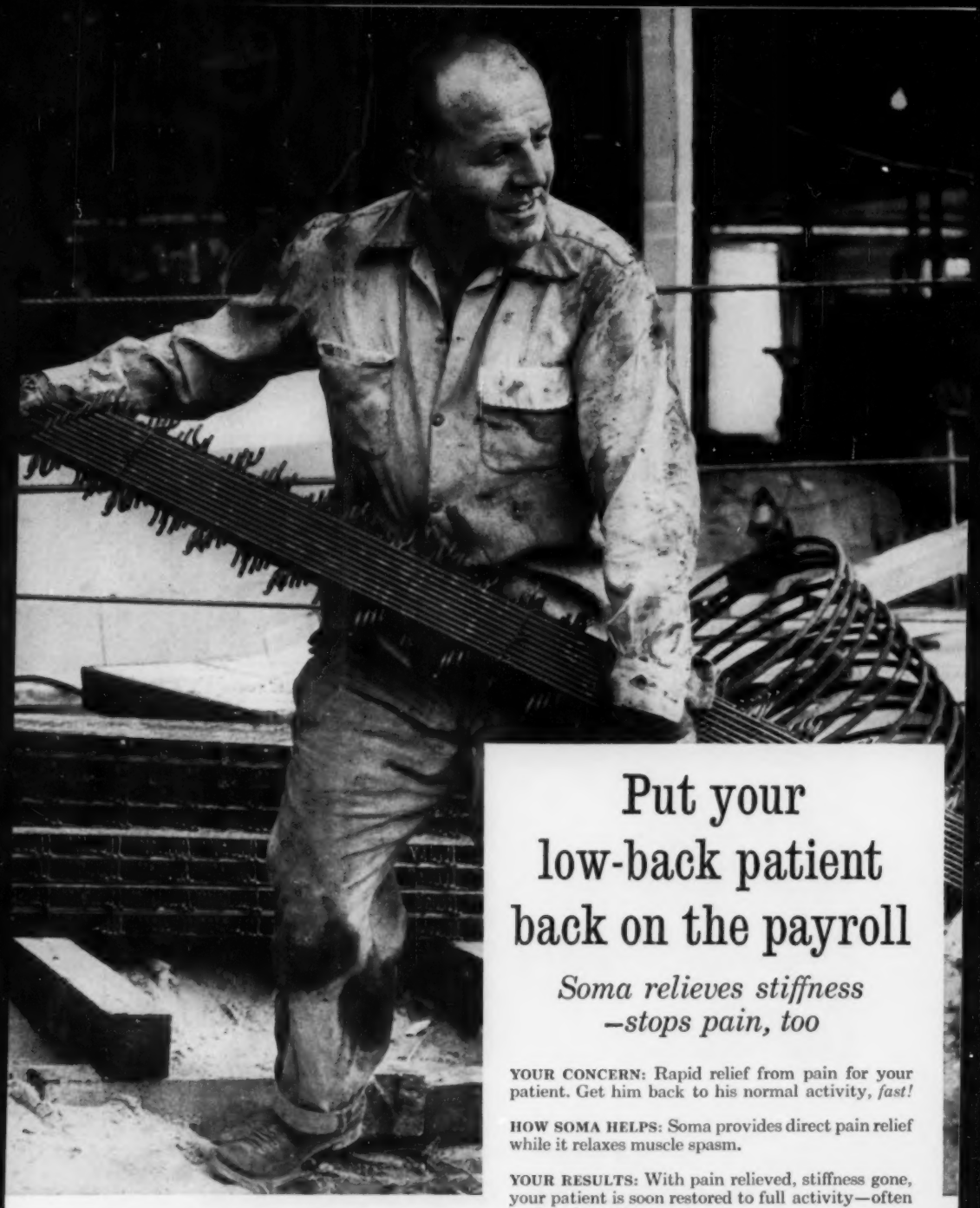

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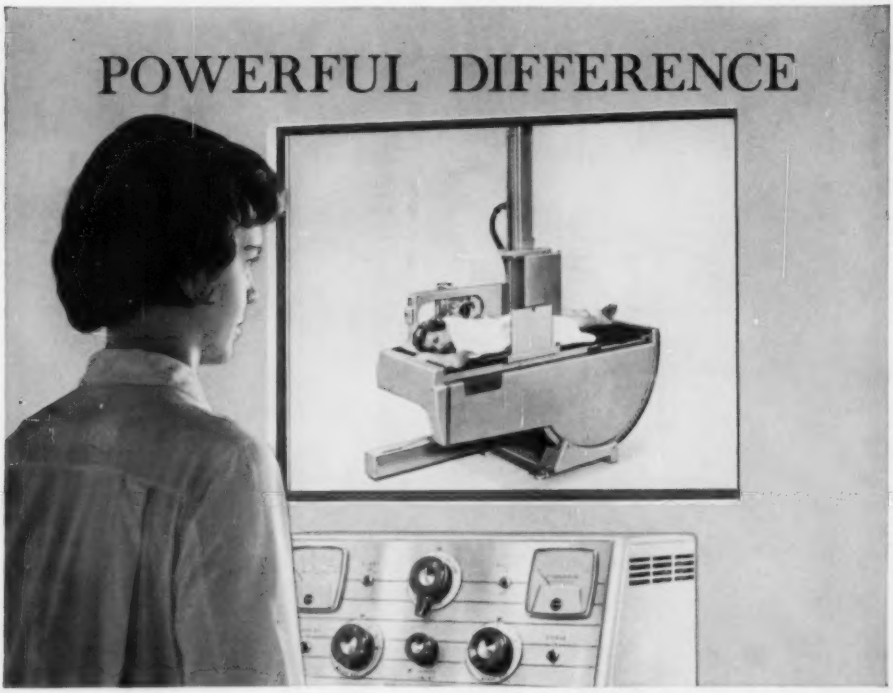

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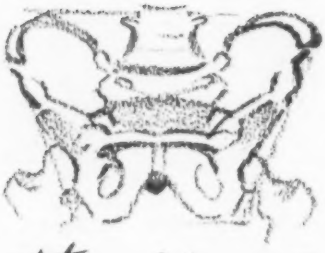

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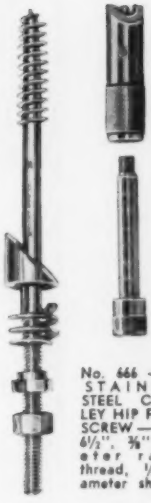

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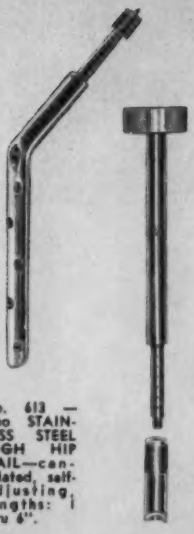

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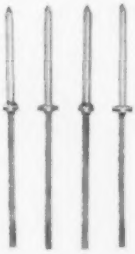

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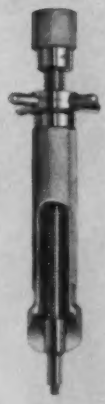

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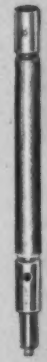

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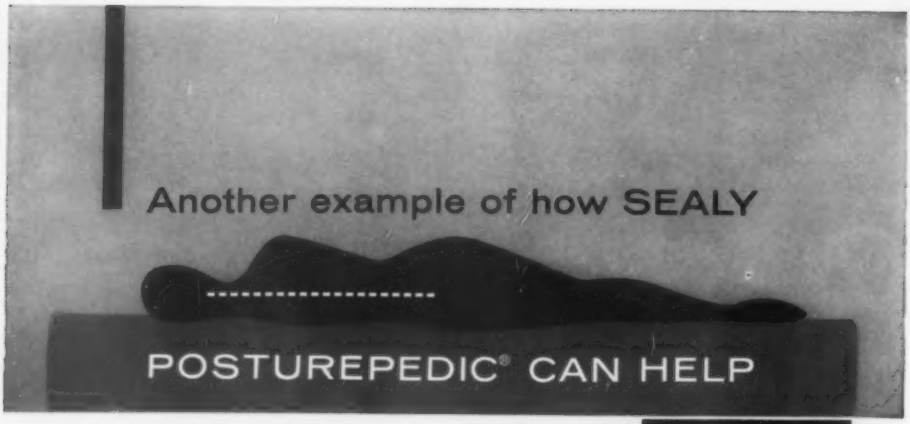

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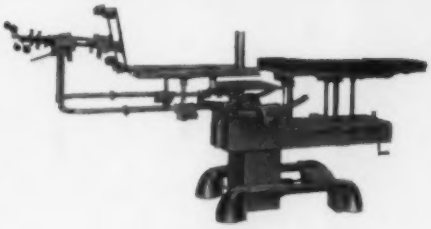

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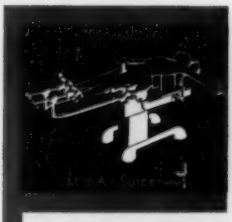

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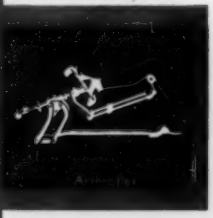

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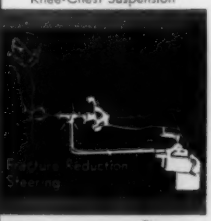

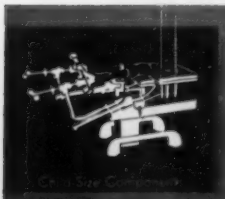

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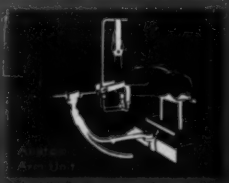

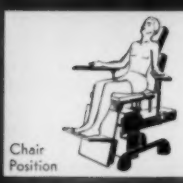

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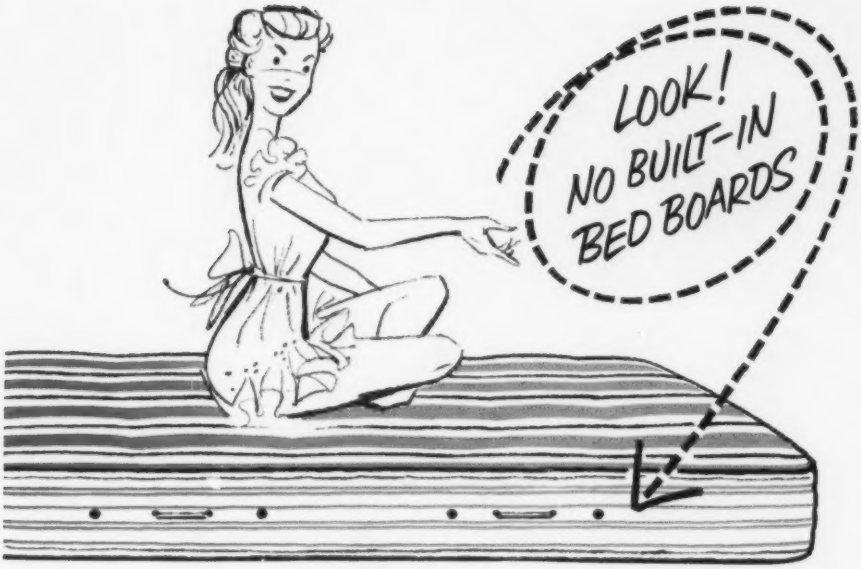

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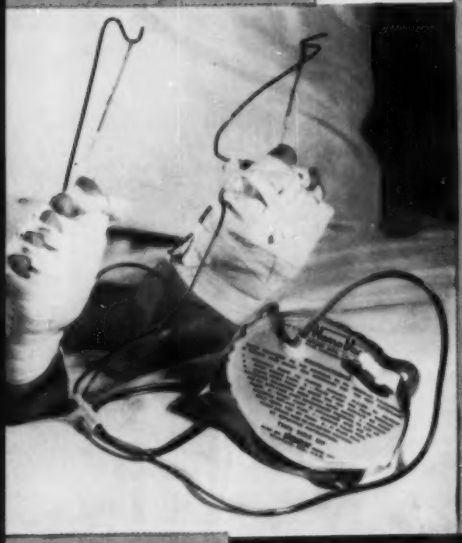

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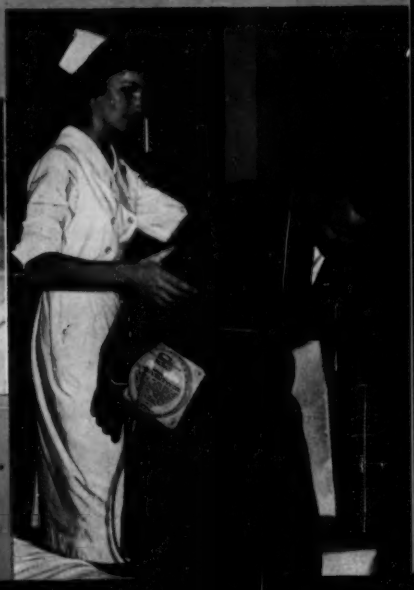

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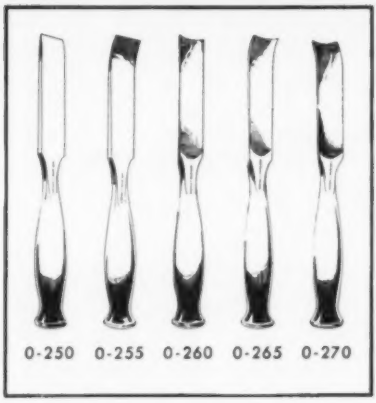

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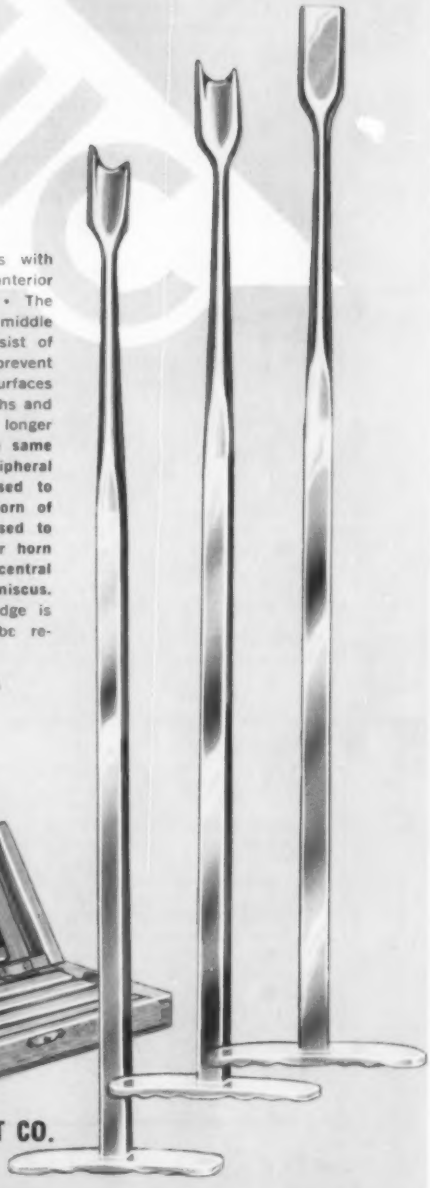

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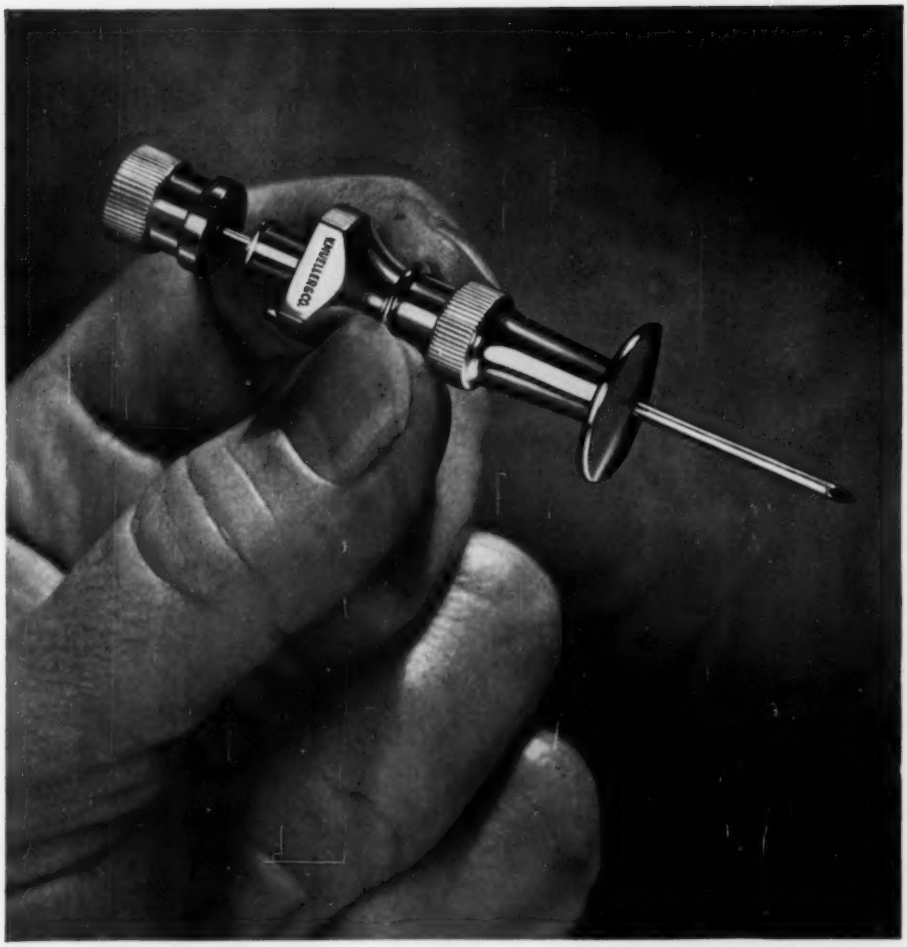

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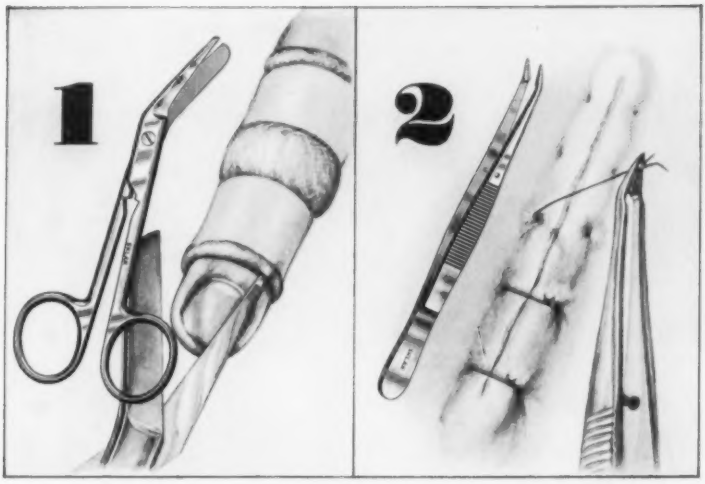

specifically designed for the purpose

1 Burnham Finger Bandage Scissors

Minimizes pain caused by conventional acorn tip ...thin lower blade with rounded tip slips easily under bandage... notched shank facilitates ready removal of needles frozen to syringes...provides leverage to shear through heavy dressings —yet compact and light enough for the pocket.

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Both instruments precision made of stainless steel by SKLAR, Long Island City, N.Y.
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Designed to assist in passive abduction after cup arthroplasty, rehabilitation of paraplegics, and many other cases requiring weight controlled exercises.

- Rigid Construction—Relatively Light in Weight
- Moves Freely on Ball Bearings in All Directions
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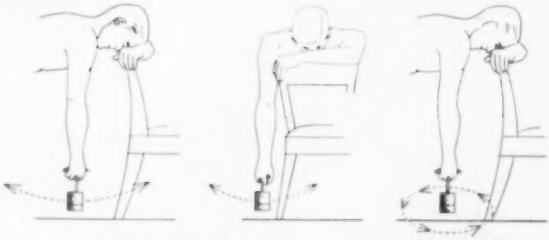
ORMANDY PENDULUM EXERCISER

To Prevent Frozen Shoulder

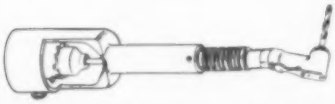
An excellent means to RELIEVE MUSCLE SPASM and PAIN of the shoulder girdle by traction in order to increase the ARC OF MOTION of the scapulo-humeral joint.



Efficient Method of Exercising for Shoulder—Joint Injuries

To Prevent Frozen Shoulder

The compact size of the Pendulum Exerciser will make it possible to increase the arc of motion without hitting the leg of the patient.



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Designed Especially for the Bobkhart Operation

Excellent for bone surgery at difficult angles and in restricted areas requiring use of drills, curetting burrs, slotting burrs. Rigidly contructed, light in weight. Entire unit may be sterilized. Two 3/32 inch diameter High Speed Drills supplied with each attachment.

Easily attached to Jacobs chuck with key.

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GONIOMETER— Pocket Size Anodized Aluminum

A Pocket Size instrument with calculation flexibility allowing complete angle determination in degrees.

Produced from aluminum, anodized and dyed black, with white-lead-filled penetration of radiation and full penetration of radiation of screening a permanent secondary shadow of measurement on the film for consultations and computations.

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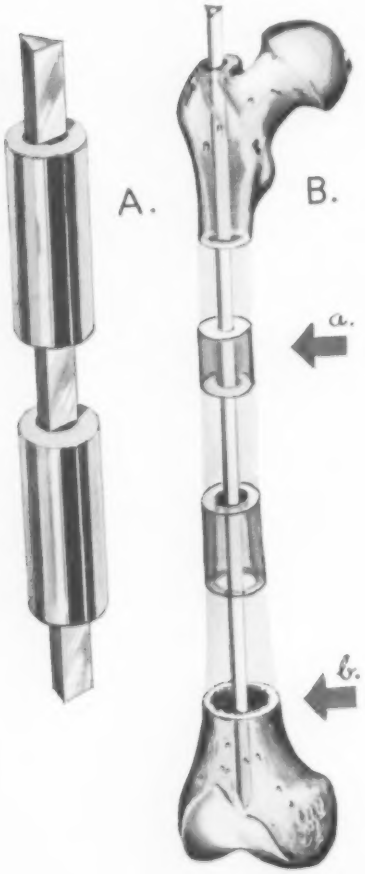
PAT. NO. 2,579,968

Where is the Tight Rod Tight?



(A) A rod can be tightly impacted in a hollow pipe to control rotation because a pipe is of even contour and diameter throughout its entire length.

The medullary cavity of a bone, however, varies both in contour and diameter at various levels. A rod tightly impacted at one level will be loose at another.

(B) **Example femur.** A fracture of the upper half of the femur can be securely transfixed by any type of medullary rod because in this region, the bone is of fairly even diameter.

The medullary cavity is narrowest at the isthmus (a). The lower half of the medullary cavity is large and trumpet-shaped (b).

Any rod, which will pass through the isthmus (a), regardless of its shape in cross section, will be loose in the bone at (b)

Such a rod driven straight into the distal fragment must depend solely upon the doubtful firmness of the cancellous bone of the condyles for stability and the prevention of rotation of the lower fragment.

This is reliable only in young, active individuals. Cancellous bone has little substance in debilitated and inactive adults, and is almost absent in the elderly.

It thus becomes apparent that for stability of fixation of the lower fragment, the surgeon must depend not upon the irregularity of cross section of a straight rod, but upon the more dependable dynamic factors which can be utilized.

Femur Shaft Technics

For **precise** fixation the technic must vary at different levels because of the trumpet interior of the femur.

(A) Pinning not indicated except in young individuals.

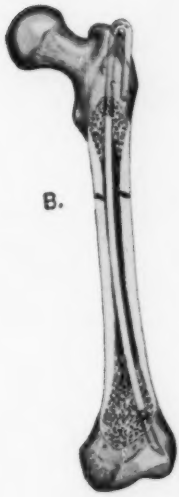
(B) Note modification of head of pin for stable fixation of upper fragment to prevent rotation and angulation.

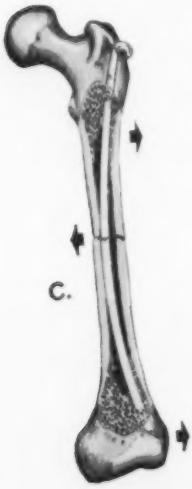
(C) Single curved pin gives stable fixation by 3-point pressure.

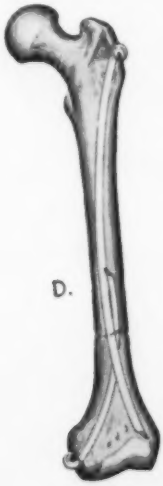
(D) Lower fragment is the problem. Addition of pin from internal condyle enhances stability.

(E) Bag of bones fracture fixed by double pins. Can usually be done as closed procedure. Spread of pins maintains length. Fascial envelope compresses fragments.

(F) Supra condylar and T fractures usually pinned as closed procedure.







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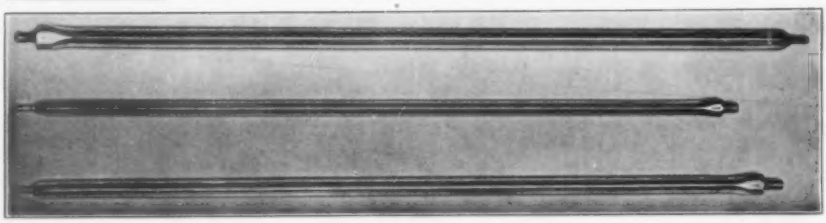
Publishers of "ATLAS OF RUSH PIN TECHNICS" by LESLIE V. RUSH, M. D.

LOTTES NAILS and INSTRUMENTS



***LOTTES* FEMORAL NAILS** are manufactured with diameters of 3/8, 7/16, and 1/2 inches —with lengths in 1/2 inch variations from 14 to 20 inches.

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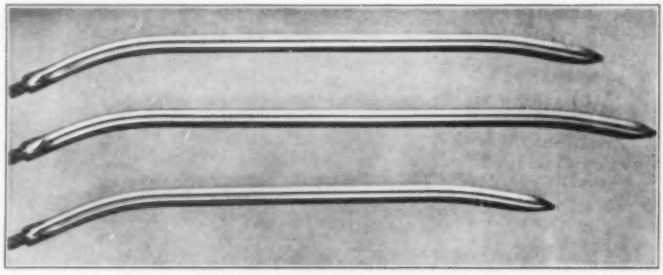

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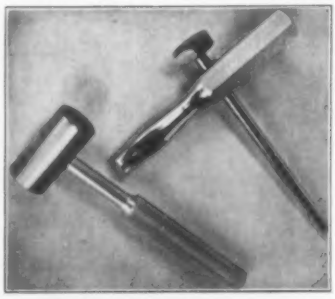

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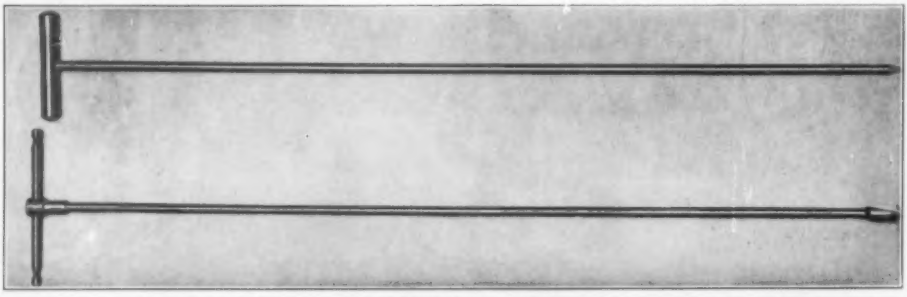
The reamer comes in 3 diameters: 3/8, 7/16, and 1/2 inch—all are 23 inches in length.



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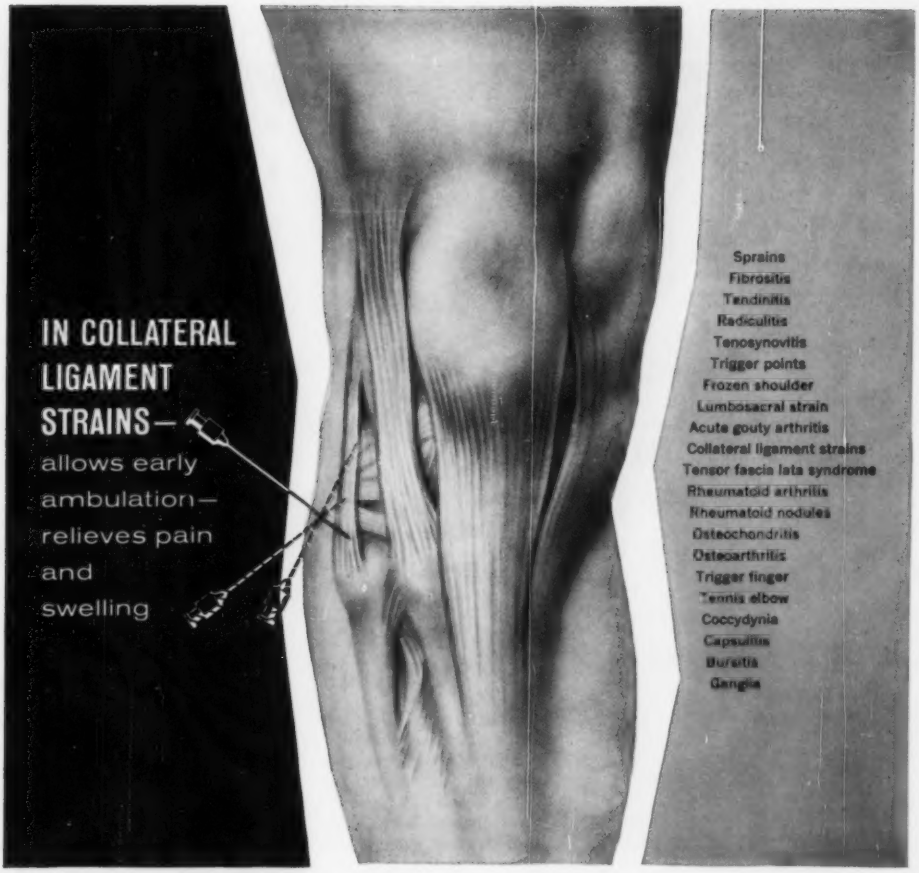

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No. 1400 OPEN TOE
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Lace-to-toe design permits snug, gentle fit. Perfectly smooth inside.

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Louis C. Weld, President of G. W. Chesbrough Co. . . . "My own personal experience led to the development of the new Chesbrough Shoe."

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Any parent whose child requires orthopedic correction knows the expense is great, as frequent purchase of new shoes is required.

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All shoes in unlined white elk, sizes 000 to 4, narrow and wide. Available in full pairs, split pairs or single shoes (no extra charge for half pairs).

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For those patients requiring immediate and quite rigid spinal support, a basic brace by Truform may well be your best recommendation. Two frequently needed braces are pictured below . . . a number of other types are also available. You can always rely on Truform braces and supports that are anatomically correct and therapeutically sound . . . fitted by skilled technicians . . . available only from the Ethical Appliance Dealer.

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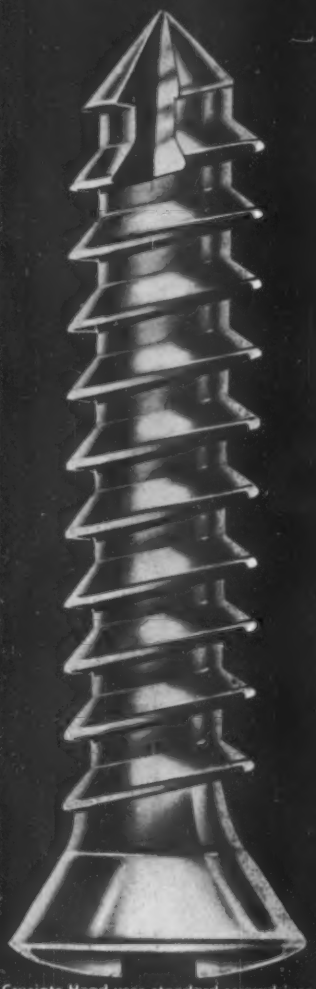
Bechtol Radial Fluted Point



Cruciate Head uses standard screwdriver

NEW *Richards* BONE SCREW

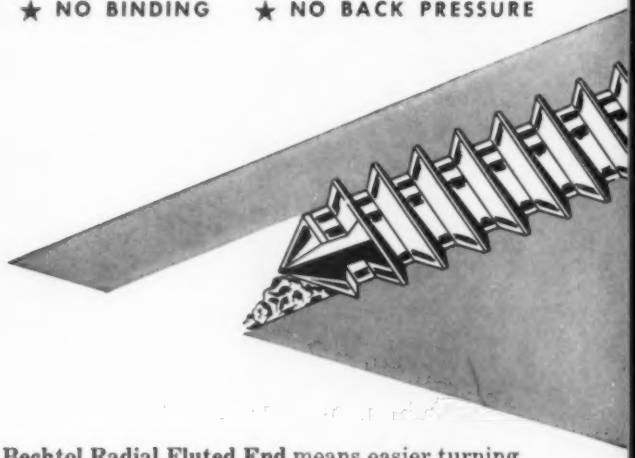
(SMO Stainless)

with Bechtol Radial Fluted Point

and buttress threads

★ TURNS EASIER ★ HOLDS BETTER

★ NO BINDING ★ NO BACK PRESSURE



Bechtol Radial Fluted End means easier turning because flutes move bone crumbs ahead, prevent them from clogging threads and causing screw to bind. Tests prove 50% less torque is required.

Buttress threads increase screw's holding power and eliminate back pressure.

Micrometric accuracy in manufacture assures perfectly true shank for maximum ease of entry and greatest possible thread grip.

No special instruments needed. Precision-cut Cruciate Head requires standard screwdriver. Regular 7/64" diameter drill bit used. Available in standard bone screw lengths.

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NEUFELD FEMORAL NAIL PLATES

have been engineered to provide maximum strength at the bend. Available in either Neutrilium (cobalt alloy) or type 316 stainless steel with screws of identical metals . . . The Neufeld nail is the choice of careful, discriminating orthopedic surgeons.

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NEW PARAFON®

Combining a superior skeletal muscle relaxant[1-3] with a preferred musculoskeletal analgesic,[4,5] *new* PARAFON FORTE rapidly relieves *both* pain and muscle stiffness in low back disorders. Thus, the effective dual action of PARAFON FORTE increases the patient's range of motion and hastens recovery. PARAFON FORTE is equally effective in other musculoskeletal disorders, such as myositis, whiplash injuries, strains or sprains, and fibrositis. Side effects are rare, almost never require discontinuation of therapy.

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Dosage: Two tablets q.i.d. *Supplied:* Scored, light green tablets, imprinted "McNEIL," bottles of 50.

References: (1) Settel, E.: Clin. Med. *6*:1373, 1959. (2) Peak, W. F., and Smith, R. T.: Penn. Med. J. *62*:833, 1960. (3) Mayle, F. C.; Sullivan, F. D., and Auth, T. L.: Med. Ann. D. C. *28*:499, 1959. (4) Roth, J. L. A.: Med. Clin. N. Amer. *41*:1517, 1957. (5) Batterman, R. C., and Grossman, A. J.: J.A.M.A. *159*:1619 (Dec. 24) 1955.

*U.S. Patent No. 2,895,877

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New Tensor almost fastens

Handy attached clip saves time and tempers–takes hold at a touch, can't be lost or dropped!

Now Bauer & Black makes the bandage and clip into one.

The built-in clip fastens easier and faster than anything you've ever used before. You need never again be annoyed by loose, lost, or dropped clips. Or waste time having to hunt up a substitute safety pin or adhesive tape.

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It's a really big step forward in effectiveness and convenience, yet these improvements haven't pushed the price up one cent! You'll be glad you specified it.

Stretch in the Tensor elastic bandage is carefully engineered to provide a wide range of safe usability. And heat-resistant rubber means long bandage life, despite frequent washing and drying.

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ATTACHED-CLIP
ELASTIC BANDAGE

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elastic bandage itself... *because the clip is built right in*

3 vital considerations in relief of pain and restoration of function in hip pathology

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"Artificial prostheses for replacement of the upper end of the femur deserve a place in our armamentarium of treatment of hip disease."[1]

Choice of **Vitallium**®

"We believe that the cobalt-chrome alloys [VITALLIUM] have in clinical experience proved to be so superior in all respects to the existing stainless steels that they should now be very seriously considered for all surgical implants."[2]

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"... the Austin Moore intramedullary VITALLIUM prosthesis [is] one of the best prostheses available at the present time."[3]

Advantages of Hip Arthroplasty:

- Pain and disability relieved in most cases
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For further information about VITALLIUM appliances, consult your surgical dealer or write to Austenal Company.

REFERENCES: 1. Swanson, F.G.: Wisconsin Med. J., 39:181, 1940. 2. Scales, J. T., and Zarek, J.M.: J. Bone & Joint Surg. 37-B:827, 1955. 3. Merchant, F.: Rocky Mountain M.J. 56:47, 1959. 4. Callahan, J.J.: In: Clin. Med. America, W.B. Saunders Co., Philadelphia, Feb. 1957, p. 139.

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VITALLIUM is a registered trade mark of the Austenal Company applied to certain cobalt-chromium alloys and to surgical appliances made from those alloys.

"[Its] unique suitability for surgical appliances derives from its inherent corrosive resistance, its compatibility with human tissues, its inertness and freedom of electrolytic activity, together with its toughness and strength."[4]

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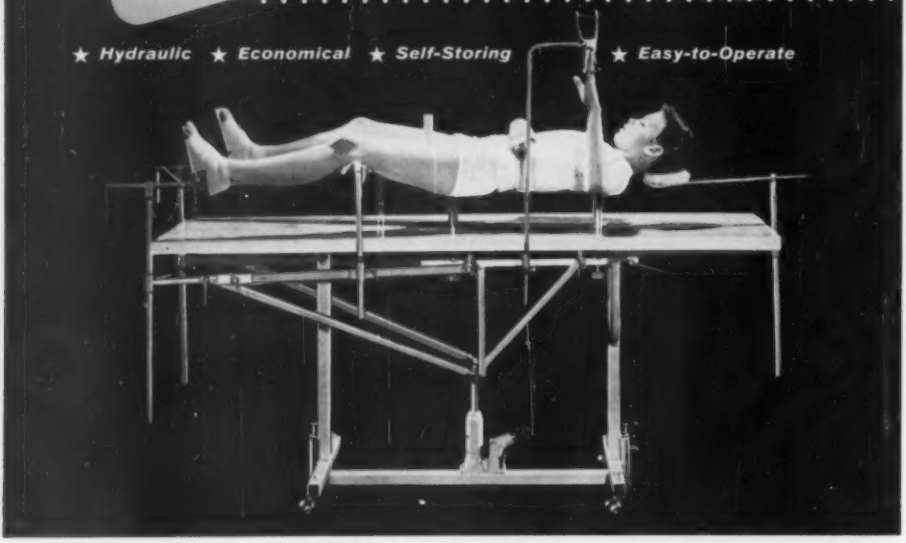

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PLUS THESE EXCLUSIVE EXTRAS:

Heel and sole plate separate and pull out, after plaster is wrapped around foot. Leg and knee, in place, can be moved laterally as required.

Simplified toe and finger clamps hold the extremity for you with no more pressure than you would hold it yourself.

Floor stops stabilize the table, prevent movement.

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The Journal of
Bone and Joint Surgery

American Volume

In Appreciation

Manuscripts submitted to the American Volume of The Journal concern many aspects of the art and science of orthopaedic surgery and arrive at 8 The Fenway with relentless regularity winter and summer without respect for vacations or other circumstances. The Associate Editors, appointed by the Editor, subject to the approval of the Journal Trustees, from the membership of The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, and the American Society for Surgery of the Hand, are not qualified to give expert opinion on all subjects nor can they always stem the rising tide of manuscripts awaiting review because of vacations or other commitments.

To solve these problems The Journal has for many years sought the help of authorities in other fields and of orthopaedic surgeons who by interest and inclination are qualified and willing to help out. We have enjoyed the assistance of such varied specialists as pathologists, neurosurgeons, neurophysiologists, civil engineers, and biophysicists, to mention but a few. Some of these consultants have given us assistance on many occasions, others have filled crucial gaps in our knowledge on but one occasion.

In the past these consultants have worked uncomplainingly with no more recompense than a letter of thanks from the Editor (sometimes, regrettably, not even that), although one consultant did remark plaintively some time ago that he did more work for The Journal with which he had no official connection than he did as a member of the editorial board of a journal concerned with his own specialty.

Belatedly, we have resolved to give credit where credit is due. In this final issue of the 1961 Volume, we take great pleasure in acknowledging our indebtedness to the following men for their invaluable assistance during the last three years. Not included in this list are former Associate Editors who have helped out from time to time and the many consultants, countrywide, whose opinions have been obtained independently by Associate Editors. To these men we are also most grateful.

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Curtiss, Paul H., Jr., Cleveland, Ohio
Dodge, Philip R., Boston, Massachusetts
Dziewiatkowski, Dominic D., New York, N.Y.
Evans, Edward T., Minneapolis, Minnesota
Evans, F. Gaynor, Detroit, Michigan
Ferris, Benjamin G., Jr., Boston, Massachusetts
Forsyth, H. Francis, Winston-Salem, North Carolina
Gamstorp, Ingrid, Lund, Sweden
Gardner, Ernest D., Detroit, Michigan
Gergeley, John, Boston, Massachusetts
Green, William T., Boston, Massachusetts
Griesemer, R. D., Boston, Massachusetts
Gross, Jerome, Boston, Massachusetts
Hamlin, Edward, Jr., Boston, Massachusetts
Hanelin, Joseph, Newton, Massachusetts
Hansen, Robert J., Cambridge, Massachusetts
Hardy, Harriet L., Cambridge, Massachusetts
Harris, William H., Boston, Massachusetts
Hatcher, C. Howard, Palo Alto, California
Henneman, Philip H., Jersey City, New Jersey
Howard, Lot D., Jr., San Francisco, California
Jacobson, Bernard M., Boston, Massachusetts
Jaffe, Henry L., New York, N.Y.
Johnson, J. T. H., Baltimore, Maryland
Johnson, Lent, Washington, D.C.
Jones, William Norman, Boston, Massachusetts
Kahn, Edgar A., Ann Arbor, Michigan
Kane, Lewis, Boston, Massachusetts
Kass, Edward H., Boston, Massachusetts
Krane, Stephen M., Boston, Massachusetts
Littler, J. William, New York, N.Y.
Lowell, J. D., Boston, Massachusetts
Mark, Vernon H., Boston, Massachusetts
Markee, J. E., Durham, No. Carolina
Mazet, Robert, Jr., Los Angeles, California
McLean, Franklin C., Chicago, Illinois
Mills, John, Boston, Massachusetts
Nemiah, John C., Boston, Massachusetts
Neuhauser, Edward B. D., Boston, Massachusetts
Nicholas, James A., New York, N.Y.
Norton, Paul L., Boston, Massachusetts
Phalen, George S., Cleveland, Ohio
Ponseti, Ignacio V., Iowa City, Iowa
Robbins, Laurence L., Boston, Massachusetts
Rowe, Carter R., Boston, Massachusetts
Schwab, Robert, Boston, Massachusetts
Shaw, Robert S., Boston, Massachusetts
Sherman, Mary S., New Orleans, Louisiana
Short, Charles L., Boston, Massachusetts
Smith, Alan DeForest, New York, N.Y.
Sweet, William H., Boston, Massachusetts
Swenson, Orvar, Boston, Massachusetts
Taft, Edgar B., Boston, Massachusetts
Taylor, Grantley W., Weston, Massachusetts
Todd, Donald P., Boston, Massachusetts
Tonna, Edgar A., Upton, Long Island, New York
Twitchell, Thomas E., Boston, Massachusetts
Van Gorder, George W., Newton, Massachusetts
Warkany, Josef, Cincinnati, Ohio
Watkins, Arthur L., Boston, Massachusetts
White, James C., Boston, Massachusetts
Williams, Paul C., Dallas, Texas
Wyman, S. M., Boston, Massachusetts

Posterior Fracture-Dislocations of the Hip

Comparison of Open and Closed Methods of Treatment in Certain Types *

BY HERMAN C. EPSTEIN, M.D., BEVERLY HILLS, CALIFORNIA

It is the purpose of this report to compare the results of open reduction of certain fracture-dislocations of the hip with the results obtained by closed methods. The objective of open reduction is to remove all loose fragments from the joint space, to restore stability to the joint by open reduction and fixation of any large fragments from the posterior rim of the acetabulum, and to assure accurate reduction of the dislocation. The findings in this study show that in certain types of fracture-dislocation, open reduction gives better results than those attained by closed methods.

In April 1953, I operated on a patient with a comminuted fracture of the acetabulum associated with dislocation of the hip. Open reduction could not be done until thirteen days after injury. At operation many small fragments were removed from the joint and a large fragment of the acetabulum, including the posterior rim, was reduced and held in position by two screws. Twelve months later, the result was rated *good* without any evidence of avascular necrosis or traumatic arthritis; eighty-four months later, the result was still good.

The favorable result in this case prompted a re-evaluation of the fracture-dislocations of the hip reported by Thompson and me in 1951. This re-evaluation emphasized that poor results occurred when open reduction was delayed or when fracture-dislocations that were presumed to have small, loose fragments within the joint space were treated by closed methods. In our study in 1951, we proposed the following classification for fracture-dislocations of the hip:

Type I: with or without minor fracture;

Type II: with a large single fracture of the posterior acetabular rim;

Type III: with a comminuted fracture of the rim of the acetabulum, with or without a major fragment;

Type IV: with fracture of the acetabular rim and floor;

Type V: with fracture of the femoral head.

Using this classification, we found that Types II, III, IV, and V tended to do poorly with closed treatment, and it was apparent that a different method of treatment was indicated for fracture-dislocations in these four groups. The series of cases to be reported here were all thus classified. Fracture-dislocations of Type I and central fractures of the acetabulum without posterior dislocation were not included.

The following considerations led to the adoption of the method of treatment employed in the series reported here.

Although in the initial series, Type II fracture-dislocations had shown better results with closed methods than the other types, there were only a few cases treated surgically. It was therefore surmised that open reduction performed immediately after injury to permit removal from the joint of loose fragments not revealed by roentgenogram would give better results. It was also postulated that maintenance of an accurate reduction of an unstable posterior fracture-dislocation could only be assured by open reduction with fixation of the posterior lip fragment in its anatomical position.

* Based on a paper read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N.Y., February 4, 1958.

TABLE I

ROENTGENOGRAPHIC CRITERIA FOR EVALUATING RESULTS

Excellent (normal)	*Good* (minimum changes)
All of the following:	Normal relationship between the femoral head and the acetabulum
Normal relationship between the femoral head and the acetabulum	Minimum narrowing of the cartilaginous space
Normal articular cartilaginous space	Minimum deossification
Normal density of the head of the femur	Minimum spur formation
No spur formation	Minimum capsular calcification
No calcification in the capsule	
Fair (moderate changes)	*Poor* (severe changes)
Normal relationship between the femoral head and the acetabulum	Almost complete obliteration of the cartilaginous space
Any one or more of the following:	Relative increase in density of the femoral head
Moderate narrowing of the cartilaginous space	Subchondral cyst formation
Mottling of the head, areas of sclerosis, and decreased density	Formation of sequestra
Moderate spur formation	Gross deformity of the femoral head
Moderate to severe capsular calcification	Severe spur formation
Depression of the subchondral cortex of the femoral head	Acetabular sclerosis

TABLE II

CLINICAL CRITERIA FOR EVALUATING RESULTS

Excellent	*Good*
All of the following:	No pain
No pain	Free motion (75 per cent of normal hip)
Full range of hip motion	No more than a slight limp
No limp	Minimum roentgenographic changes
No roentgenographic evidence of progressive changes	
Fair	*Poor*
Any one or more of the following:	Any one or more of the following:
Pain, but not disabling	Disabling pain
Limited motion of the hip; no adduction deformity	Marked limitation of motion or adduction deformity
Moderate limp	Redislocation
Moderately severe roentgenographic changes	Progressive roentgenographic changes

In Type III fracture-dislocations the very nature of the injury was believed to make it probable that loose fragments were in the joint; hence open reduction seemed indicated for these injuries.

In the Type IV and Type V injuries, the results in the previous series were so poor that a new approach was obviously needed. When the first series was reported arthrodesis or arthroplasty was suggested as a primary procedure, but it was hoped in planning this new study that early open reduction might yield better function.

In the literature there was little to be found concerning early open reduction in the treatment of these types of fracture-dislocations, and in the 1951 series there were only twenty-five open reductions performed. Hence, there were too few cases in each category to permit adequate comparison between open and closed methods.

Experimentally, King and Richards had demonstrated that rapid disintegration occurred in the hip joints of dogs when there was incomplete reduction

of a fracture-dislocation. This disintegration appeared to be due to the mechanical incongruity of the joint surfaces.

Urist had recommended primary open reduction in dislocations associated with comminuted fractures of the acetabulum, but in his report there was no record of a patient having been treated in this way. Gordon and Freiberg, in discussing a Type V dislocation, recommended excision of the loose fragment. In a series of eight patients with central fractures of the acetabulum treated by open reduction, Knight and Smith included two cases in which there was a posterior fracture-dislocation (Type IV); excellent results were reported in both of these cases.

This study was thus undertaken to test the hypothesis that the removal of loose fragments and restoration of stability of the hip by fixation of the posterior rim by primary open reduction could give better results, even though Type II fracture-dislocations had been found in the earlier series to have relatively good results after treatment by closed methods.

CLINICAL MATERIAL

The present report is based on a study of 149 dislocations of the hip, which were treated at the Los Angeles County Hospital from July 1950 to June 1957, and three private patients treated by me. From these 152 cases, eight anterior and eighty posterior dislocations without fracture were eliminated since this study was not planned to include injuries of this type. Several previous reviews of the results of treatment of simple dislocations have been published [1,7,8,9]. Only one open reduction was performed in the eighty-eight patients not included in this series. The procedure was done for a posterior dislocation which could not be reduced by closed methods and immediate open reduction was performed; the result in this case, five years later, was good.

With the eighty posterior and eight anterior dislocations eliminated, there remained sixty-four fracture-dislocations, only fifty-five of which were adequately followed. Among the patients with adequate follow-up, sixteen were treated by closed manipulation and thirty-nine had open reduction. The open reductions were performed primarily without prior attempt at closed reduction in twenty-three and after closed reduction in fourteen. The remaining two cases were initially unrecognized fracture-dislocations that were subsequently treated by open reduction. The results of the thirty-nine open reductions were known in thirty-seven cases including twenty-three of the twenty-seven primary open reductions.

METHOD OF STUDY

The results were classified *excellent*, *good*, *fair*, or *poor* according to the roentgenographic (Table I) and clinical (Table II) criteria previously used [8]. The patient's hospital record and roentgenograms were reviewed, and all patients were re-examined at least one year after treatment unless the result was fair or poor, in which case a follow-up period of less than one year was accepted. Thus, there were thirty-seven cases, eighteen being primary open reductions, that were followed for more than two years; eight cases with good results followed for twelve to eighteen months; and ten cases with fair or poor results followed for less than one year. The average follow-up period was forty months.

OPERATIVE TECHNIQUE

The surgical approach used in the primary open reductions was the same as that first described by Griswold and Herd in 1929 and later used by King and Richards. The operation is done under endotracheal anesthesia, with the patient

TABLE III

PRIMARY OPEN REDUCTION
1950 TO 1957
RESULTS IN TWENTY-THREE CASES

Type of Fracture-Dislocation	No. of Cases	No. of Results		
		Good	Fair	Poor
II	6	5	1	0
III	7	6	0	1*
IV	2	1	1	0
V	8	5	2	1†
Totals	23	17	4	2

* Patient died at operation
† Hip became infected

TABLE IV

TYPE II: 1950 TO 1957
RESULTS IN FIFTEEN POSTERIOR FRACTURE-DISLOCATIONS

Method of Reduction	No. of Hours Before Reduction	No. of Cases	No. of Results		
			Good	Fair	Poor
Closed	Under 24 hrs.	4	2	2	0
	Over 24 hrs.	0	0	0	0
Closed, followed by open	Under 24 hrs.	0	0	0	0
	Over 24 hrs.	5	4*	1†	0
Primary open	Under 24 hrs.	6	5	1	0
	Over 24 hrs.	0	0	0	0
	Totals	15	11	4	0

* One open reduction, one month; two open reductions, five days; and one open reduction, two months after injury.
† Surgery three months after injury.

placed in a prone position. The incision extends from the posterior superior iliac spine outward and downward to the region of the greater trochanter. For more adequate exposure the incision can be extended further laterally through the aponeurosis of the gluteus maximus and tensor fasciae latae. Very little bleeding is encountered if the gluteus maximus muscle is split with blunt dissection rather than incised with a sharp instrument. The areolar and fatty tissue in the region of the peritrochanteric bursa is removed. Before incising the short rotator muscles at their attachments to the trochanteric fossa, the sciatic nerve must be identified and retracted. After incision of the short rotator muscles—mainly the piriformis, the gemelli, and the obturator internus and obturator externus—the hip joint can be adequately visualized. If further exposure is necessary the gluteus medius is divided at its attachment to the greater trochanter. This surgical approach affords excellent exposure of the hip joint and makes it possible with the hip dislocated to visualize the whole acetabulum and to remove loose fragments. Similarly, after reduction the hip joint can be stabilized by fixing the fractured posterior acetabular rim with one or more screws if necessary.

RESULTS

In the series reported in 1951 [8], there were twenty-five open reductions performed between 1928 and 1949 with three good results; the rest were either fair or poor. The three good results occurred in the twelve Type III injuries in which open

TABLE V

TYPE III: 1950 TO 1957
RESULTS IN TWELVE POSTERIOR FRACTURE-DISLOCATIONS

Method of Reduction	No. of Hours Before Reduction	No. of Cases	No. of Results		
			Good	Fair	Poor
Closed	Under 24 hrs.	3	0	2	1
	Over 24 hrs.	0	0	0	0
Closed, followed by open	Under 24 hrs.	0	0	0	0
	Over 24 hrs.	1	0	0	1
Irreducible; open	Under 24 hrs.	1	1	0	0
Primary open	Under 24 hrs.	5	4	0	1*
	Over 24 hrs.	2	2†	0	0
	Totals	12	7	2	3

* Died at operation.
† One, two days after injury; one, thirteen days after injury.

TABLE VI

TYPE IV: 1950 TO 1957
RESULTS IN FOURTEEN POSTERIOR FRACTURE-DISLOCATIONS

Method of Reduction	No. of Hours Before Reduction	No. of Cases	No. of Results		
			Good	Fair	Poor
Closed	Under 24 hrs.	3	1	1	1
	Over 24 hrs.	4	0	0	4
Closed, followed by open	Under 24 hrs.	0	0	0	0
	Over 24 hrs.	2	1	0	1
Not recognized		1	0	0	1
Irreducible; open	Under 24 hrs.	1	0	1	0
	Over 24 hrs.	1	0	0	1
Primary open	Under 24 hrs.	2	1	1	0
	Over 24 hrs.	0	0	0	0
	Totals	14	3	3	8

reduction had been done. Only one of these three patients had a primary open reduction, but loose fragments were removed from the joint space in all three. In two other patients, the hip joint was exposed and the avulsed acetabular rim fragment was identified and reattached to the acetabulum, but no attempt was made to redislocate the hip and explore the acetabulum for loose fragments. In both of these patients small fragments undoubtedly were left in the hip joint and severe traumatic arthritis ensued. Taking the early series as a whole there was not one excellent result in any of the injuries classified as Type II to Type V inclusive.

In the present series there were twenty-three primary open reductions (Table III) and sixteen open reductions following closed manipulation performed between 1950 and 1957. There were no excellent results in this series in the patients treated by either primary open reduction, closed reduction, or secondary open operation. Since *excellent* in this classification means essentially a normal hip with no clinical or roentgenographic abnormalities, an excellent result after the severe injuries that occurred in these patients could hardly be expected.

The results in the present series of open and closed methods of treatment in each type of injury are tabulated in Tables IV to VII.

Type II (Table IV)

The six primary open reductions in this group were done within twenty-four hours after injury. All the joints contained small fragments which were not visual-

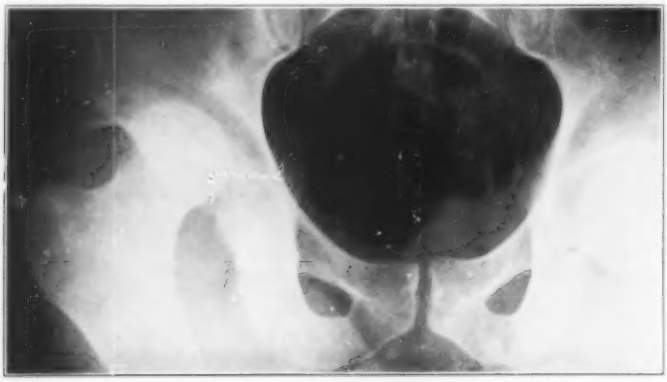

FIG. 1-A

Figs. 1-A and 1-B: O.R., a man, twenty-four years old, sustained a Type II dislocation of the right hip and a fracture of the middle fossa of the skull with cerebral concussion in an automobile accident on April 18, 1954. Primary open reduction of the hip was done on the day of the accident. The result was classified *good*.

Fig. 1-A: Roentgenogram made on the day of injury shows a large fragment off the posterior superior acetabular rim. No smaller fragments are visualized.

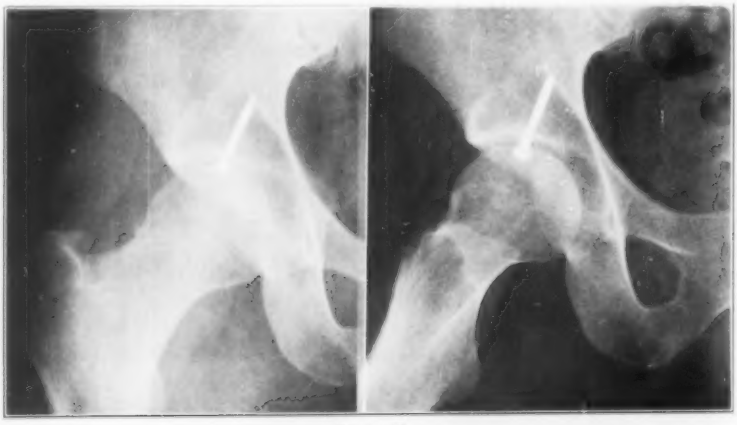

FIG. 1-B

Roentgenograms made on May 20, 1960, forty-six months after primary open reduction. Although not seen on the roentgenograms, small fragments were found and removed at surgery. In these follow-up roentgenograms, the hip joint appears normal, with one screw transfixing the fracture of the acetabular rim. There was minimum limitation only in internal rotation of the hip. At the time of writing, the patient has no hip or knee pain and works regularly as a draftsman.

ized roentgenographically (Figs. 1-A and 1-B). In another case a primary open reduction did not show these loose fragments, but this case is not included in the present series because the follow-up was insufficient. Five patients with Type II

injuries had attempted closed reduction followed by open operation from five days to three months after the injury (Figs. 2-A, 2-B, and 2-C). There were four good results and one fair result. The four closed reductions in this group produced two good and two fair results. Of the two fair results, one hip showed marked myositis ossificans and the other, traumatic arthritis.

FIG. 2-A

Figs. 2-A, 2-B, and 2-C: M.E., a thirty-year-old man, sustained a Type II dislocation of the left hip on November 30, 1952. Closed reduction, done on the day of injury, with the patient under sodium pentothal anesthesia, was followed five days later by open reduction. The patient was followed forty-four months; the result was classified *good*.

Fig. 2-A: Roentgenogram made on the day of injury.

FIG. 2-B FIG. 2-C

Fig. 2-B: Roentgenogram made on February 2, 1954, fourteen months after injury. At open reduction five days after injury, the large acetabular fragment was transfixed with two screws. There were no fragments in the hip joint. The osteotomized greater trochanter was transfixed with one screw.

Fig. 2-C: Roentgenogram made on January 12, 1955, twenty-five months after injury. The joint space is normal. There is no avascular necrosis or traumatic arthritis. The upper screw in the acetabulum has broken. The greater trochanteric fragment has not united solidly and is displaced superiorly.

When the results of open treatment of Type II injuries in the present series are compared with the results of open reduction in the earlier series, it is seen that in the eleven cases in the present series, six of which were primary reductions,

FIG. 3-A FIG. 3-B

Figs. 3-A and 3-B: L.B., a woman, twenty-six years old, sustained a Type II posterior dislocation of the right hip, with comminuted fragments, in an automobile accident. Primary open reduction was performed. The result was classified *good* at follow-up forty-five months later.

Fig. 3-A: The dislocation is revealed on this admission roentgenogram.

Fig. 3-B: A roentgenogram made after surgery shows one screw transfixing a large posterior-rim fragment. Loose fragments were removed from the joint space at surgery; arthrotomy also revealed scratch marks on the articular surface of the femoral head.

FIG. 4-A FIG. 4-B

Figs. 4-A and 4-B: R.B., a man, twenty-seven years old, sustained a Type III dislocation of the left hip in an automobile accident. At follow-up, twenty-eight months after injury, the result was rated *poor*, with avascular necrosis.

Fig. 4-A: Roentgenogram made on May 10, 1955. The dislocation had been reduced at some other hospital two days before admission. Open reduction was done on May 13, 1955. Many loose bodies were removed from the hip where a considerable amount of trauma was found, such as thrombosed veins and arteries. At operation one screw was used to fix a large fragment sheared off the posterior acetabular rim.

Fig. 4-B: A roentgenogram made on September 21, 1957, shows avascular necrosis with flattening and irregularity of the femoral head. The patient had marked limitation of hip motion with considerable pain and said he wanted to have the hip fused.

there were nine good and two fair results, whereas in the six cases in the first series there were four fair and two poor results.

Type III (Table V)

In the present series there were seven primary open reductions of Type III

injuries with six good results (Figs. 3-A and 3-B) and one poor result in a patient who died at operation because of cardiac arrest. All these hips showed many loose fragments; some were small and not visible roentgenographically, whereas others were visible, measuring 0.25 to 0.5 centimeter in diameter. All fragments were removed. One patient had an open reduction thirteen days after injury with a good result eighty-four months later. Another patient operated on three days after injury showed a good result sixty-six months later. In two patients only the loose fracture fragments were removed, since none of the fragments was large enough to fix in place and the hip in each instance was stable; both results were good.

There were two patients in whom closed reduction was followed by open reduction. In one the fracture-dislocation of the hip could not be reduced closed,

FIG. 5

A.L., a fourteen-year-old girl, in an automobile accident on February 22, 1951, sustained a Type IV fracture-dislocation of the right hip and a fracture of the ipsilateral femur. There was also cerebral concussion with sciatic paralysis. The dislocation of the hip was not recognized until April 25, 1951, when this roentgenogram of the pelvis was made to show the progress of the healing acetabular and femoral fractures. On December 12, 1951, an attempt to reduce the dislocated hip by arthrotomy proved unsuccessful because of severe soft-tissue contractures. The patient signed out against consent on January 29, 1952, at which time her result was rated *poor*. She was last seen at the hospital on February 5, 1957, when, at the age of nineteen, she delivered a normal child.

and open reduction was performed on the same day. Many small fragments of bone and cartilage were removed from the joint. A portion of the posterior capsule was found to be turned into the joint and had to be removed before reduction was possible. This hip had a good result. In the other patient, who had a closed reduction at an emergency hospital, the joint was opened three days later and the hip was redislocated. Many small fragments of bone, ranging from 0.5 to 1.5 centimeters in diameter, were removed from the joint; and a large bone fragment from the posterior superior acetabular rim was reduced and fixed with one screw. The dimensions of this fragment were much greater than was indicated by roentgenogram. The result in this hip was poor with avascular necrosis of the femoral head (Figs. 4-A and 4-B).

Type IV (Table VI)

In this group seven patients had closed reductions with one good and one

FIG. 6-A FIG. 6-B

Figs. 6-A through 6-C: W.S., a man, twenty-two years old, in an automobile accident on September 15, 1951, sustained a posterior dislocation of the left hip, with a comminuted but not grossly displaced acetabular fracture. At follow-up, six months later, the patient had traumatic arthritis and the result was rated *poor*.

Fig. 6-A: A roentgenogram made on September 15, 1951, reveals a fracture. On the first attempt at reduction the femoral head slipped anteriorly. It was pushed back posteriorly and then reduced into the acetabulum.

Fig. 6-B: Anteroposterior and lateral roentgenograms, made on October 13, 1951, reveal widening of the joint space with loose fragments within the joint. No attempt was made to remove the fragments.

FIG. 6-C

Anteroposterior and lateral roentgenograms made on March 24, 1952, reveal moderate narrowing of the joint space with increased sclerosis about the acetabulum and femoral head, which shows mottling. The lateral view shows irregularity and depression of the weight-bearing portion of the head. The patient has moderate limitation of motion of the hip with pain.

fair result and five poor results. The one good result followed a fracture through the triradiate cartilage without involvement of the weight-bearing portion of the acetabulum in a fifteen-year-old girl. In one of the patients with a poor result, closed reduction was accomplished after repeated attempts, but numerous loose bodies were left in the joint (Figs. 6-A through 6-C). In all the hips with poor results the weight-bearing surface of the acetabulum was damaged.

Seven patients had open reductions in this group. In two, the reduction was done primarily with one good (Figs. 8-A and 8-B) and one fair result, the fair result being due to avascular necrosis of the femoral head (Figs. 9-A and 9-B). Two patients had open reductions after closed reduction with one good and one poor result. The patient with the good result was operated on twenty-five days after the

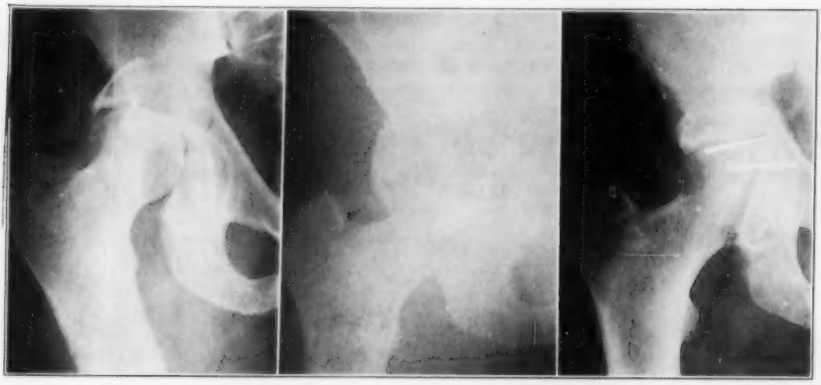

FIG. 7-A FIG. 7-B FIG. 7-C

Figs. 7-A through 7-D: C.L., a forty-year-old man, sustained a Type IV posterior dislocation of the right hip in an automobile accident on December 15, 1950. At follow-up, seven years later, the result was rated *good*.

Fig. 7-A: A roentgenogram made the day before closed reduction shows a fracture through the roof of the acetabulum with minimum displacement. The fragment avulsed from the posterior superior rim appears to be large.

Fig. 7-B: A roentgenogram made after reduction reveals lateral and superior displacement of the rim fragment. The head does not appear to have penetrated medially.

Fig. 7-C: Roentgenogram made eight months after open reduction, which was performed twenty-five days after injury. The acetabular fragment was transfixed with two stainless-steel nails, but no attempt was made to transfix the fracture through the roof of the acetabulum. No notation was made of loose fragments within the joint.

FIG. 7-D

Roentgenograms made on December 30, 1957, seven years after injury, show the joint space to be normal. There is no avascular necrosis or traumatic arthritis. There is 10 degrees limitation of internal and external rotation of the right hip; otherwise, motion is normal. The patient has never had any hip pain and has been doing heavy work without any discomfort other than occasional hip fatigue after a full day's work.

attempted closed reduction. The fracture involved the acetabular roof and posterior rim. No attempt was made to fix the fragment in the roof of the acetabulum, but the posterior rim was fixed with two nails. Eighty-four months later the result was good (Figs. 7-A through 7-D). The patient with the poor result had an open reduction two days after the dislocation was reduced by closed methods. At operation, the rim fragments were replaced and fixed with two screws after removal of loose fragments from within the joint. No attempt was made to reduce and fix the

TABLE VII

TYPE V: 1950 TO 1957
RESULTS IN FOURTEEN POSTERIOR FRACTURE-DISLOCATIONS

Method of Reduction	No. of Hours Before Reduction	No. of Cases	No. of Results		
			Good	Fair	Poor
Closed	Under 24 hrs.	2	0	0	2*
	Over 24 hrs.	0	0	0	0
Closed, followed by open	Under 24 hrs.	0	0	0	0
	Over 24 hrs.	3	0	0	3
Not recognized		1	0	0	1
Primary open	Under 24 hrs.	4	4	0	0
	Over 24 hrs.	4	1	2††	1†
	Totals	14	5	2	7

* Neck of femur fractured in attempt at closed reduction in one patient.
† Hip became infected.
†† Complication of basal-neck fracture: result at fifteen months, good; traumatic arthritis, eighteen months.

fracture in the roof of the acetabulum. This patient had such a severe injury that it was difficult to expose the joint satisfactorily.

Two dislocations were irreducible by closed methods; after open reduction the result was fair in one and poor in the other. The patient who had the poor result had an open reduction the day after the attempt at closed reduction. Three bone fragments, approximately three by two centimeters in diameter, were found within the acetabulum. These prevented the reduction of the dislocation by closed

FIG. 8-A FIG. 8-B

Figs. 8-A and 8-B: A.B., a man, thirty-nine years old, sustained a Type IV posterior dislocation of the right hip with peroneal palsy in an automobile accident. Primary open reduction was performed, and the result was rated *good*.

Fig. 8-A: A roentgenogram made on September 28, 1955, shows a large fracture of the posterior superior acetabular rim extending through the floor and rim of the acetabulum.

Fig. 8-B: Roentgenogram made on April 30, 1960, fifty-four months later. At primary open reduction there were many loose fragments in the joint. The large acetabular-rim fracture was transfixed with one screw, but no attempt was made to transfix the fracture through the floor of the acetabulum. At last follow-up, the peroneal-nerve paralysis had recovered completely, there was minimum restriction of motion of the hip, and the patient was working regularly as a salesman, free of hip pain.

methods. Difficulty was encountered in removing these fragments as the entire acetabulum appeared to have been crushed. No attempt was made to replace the bone fragments since the hip was fairly stable, except on external rotation.

In the other dislocation that was irreducible by closed methods, the hip was opened on the day of injury. Several small fragments of the posterior rim were removed since it was impossible to replace and fix them with screws. There were many small loose fragments within the joint and there was extensive contusion of the cartilage on the femoral head.

FIG. 9-A

Figs. 9-A and 9-B: E.M., a woman, thirty-nine years old, sustained a Type IV posterior dislocation of the left hip in an automobile collision. Primary open reduction was done the day of injury. At follow-up, the result was rated *fair*, with avascular necrosis of the femoral head.

Fig. 9-A: Roentgenogram made on June 30, 1956, the day of injury, reveals a fracture through the floor and rim of the acetabulum.

FIG. 9-B

Roentgenograms made on January 14, 1959, thirty months after injury, show moderate narrowing of the joint space with a depression over the weight-bearing portion of the femoral head and areas of increased and decreased densities. At open reduction, the day of injury, one screw was used to transfix the large acetabular fracture of the posterior rim; no attempt was made to reduce the fracture through the floor of the acetabulum. At the time these roentgenograms were made the patient walked with a limp and had limited motion of the hip. There was numbness in the left great toe which had persisted since the accident, but there was no weakness in the muscles of the foot. Three months later, at the last follow-up, she was walking much better, using a cane.

There was one unrecognized dislocation in this group in a patient with a fracture in the middle one-third of the ipsilateral femoral shaft. When the dislocation was recognized two months after injury, open reduction was attempted with-

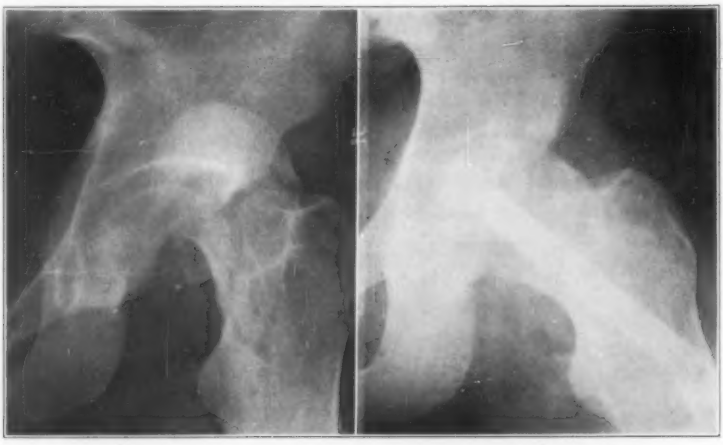

FIG. 10-A FIG. 10-B

Figs. 10-A, 10-B, and 10-C: J.H., a man twenty-six years old, in an automobile collision on December 5, 1953, sustained a Type V dislocation of the left hip with basal-neck fracture, cerebral concussion, and fractures of the middle third of both femora. At follow-up, forty-eight months after open reduction, the result was rated *fair*.

Fig. 10-A: A roentgenogram made on December 5, 1953, reveals the basal-neck fracture and a large fragment of the femoral head lying in the acetabulum. Open reduction, six days after injury, consisted in removal of the head fragment and insertion of a Neufeld nail across the fracture site.

Fig. 10-B: The fractures are reduced and the Neufeld nail is in place.

FIG. 10-C

Anteroposterior and lateral roentgenograms made on December 6, 1957, forty-eight months after injury. The Neufeld nail had been removed on July 15, 1956, thirty-one months after open reduction. At the time these roentgenograms were made the patient had moderate restriction of hip motion with soreness and aching of the hip after too much exercise. He was, however, able to bowl, swim, and perform his normal work in the electrical supply business.

out success because of the severe soft-tissue contractures; the result was poor.

In all the cases with fair or poor results in this group the fracture involved the weight-bearing portion of the acetabulum.

Type V (Table VII)

Eight of the fourteen injuries of this type were treated by primary open procedures with five good results, two fair results, and one poor result. The poor result

FIG. 11-A FIG. 11-B

Figs. 11-A, 11-B, and 11-C: J.M., a man, twenty-nine years old, sustained a Type V dislocation of the left hip and a supracondylar fracture of the left femur. Primary open reduction was done eight days after injury. At follow-up, sixty-one months later, the result was rated *good*.

Fig. 11-A: A roentgenogram made on February 23, 1955, shows the fractured portion of the head in the acetabulum. The patient was unconscious and in such poor condition that he could not be operated on until eight days after injury.

Fig. 11-B: Roentgenogram made on March 1, 1955, after open reduction, in which approximately one-fourth of the medial portion of the femoral head was removed. Loose fragments were also found within the hip joint.

FIG. 11-C

Anteroposterior and lateral roentgenograms made at follow-up, April 26, 1960. There is no avascular necrosis, the joint space is normal, and there is minimum soft-tissue calcification. The patient has good range of motion, without pain, and is able to sit for hours without having to get up.

was due to an infection. In one patient the fair result was obtained in a hip where a basal-neck fracture accompanied the dislocation (Figs. 10-A, 10-B, and 10-C). The inferior one-third of the femoral head which had been sheared off was removed, and a Neufeld nail was used for fixation of the fracture of the neck. Avascular necrosis of the femoral head ensued, but despite moderate limitation of hip motion with pain on strenuous exercise, the hip still remains serviceable forty-eight months after operation. In the other patient with a fair result, three linear excoriations were found in the cartilage of the remaining portion of the head at the time of surgery. At fifteen months the clinical roentgenographic ratings were

FIG. 12-A FIG. 12-B

Figs. 12-A, 12-B, and 12-C: P.E., a man, thirty-nine years old, sustained a Type V dislocation of the left hip and a fracture of the femoral neck after being thrown from a car during an automobile accident. Treatment included primary open reduction of the dislocation, fixation of the fracture of the femoral neck with Moore pins, and subsequent bone-grafting. At follow-up, eighteen months later, the result was rated *good*.

Fig. 12-A: Roentgenogram made on the day of injury, June 30, 1956. Note the comminuted fragments about the head with the fracture through the femoral neck.

Fig. 12-B: Roentgenogram made on July 2, 1956. At primary open reduction, ten hours after injury, several loose fragments from the femoral head were removed from the hip joint. The femoral head was attached to the neck by a small amount of periosteum. This attachment remained intact after reduction was accomplished. Two Moore pins were inserted across the fracture site.

FIG. 12-C

Anteroposterior and lateral roentgenograms made at follow-up, January 4, 1958. On August 2, 1956, a bone graft from the ilium was placed across the neck of the femur into the head, and an additional Moore pin was inserted. The follow-up roentgenograms show that the fracture healed well; there is minimum soft-tissue calcification around the hip joint and no evidence of avascular necrosis. Follow-up examination revealed good range of motion, without pain. The patient stated that he had been doing light work regularly during the past six months and was able to sit for hours without any aching, pain, or discomfort.

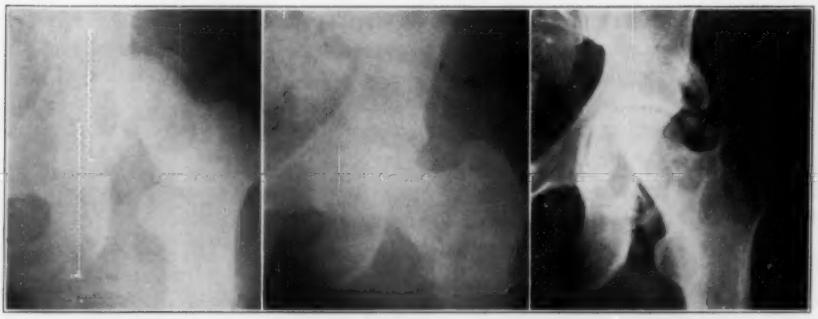

FIG. 13-A FIG. 13-B FIG. 13-C

Figs. 13-A, 13-B, and 13-C: A.G., a man, thirty-two years old, sustained a Type V posterior dislocation of the left hip in an automobile accident on August 20, 1955. At follow-up, one year after injury, the result was rated *poor*.

Fig. 13-A: A roentgenogram made on the day of injury reveals a portion of bone, which appears to be off the femoral head, lying inferiorly and superiorly.

Fig. 13-B: Reduction by closed method is apparent after two previous unsuccessful attempts. Open reduction was performed four days later, with removal of the medial one-half of the weight-bearing portion of the head. The fragment measured two inches in diameter and one inch in thickness.

Fig. 13-C: A roentgenogram made one year later shows a minimum amount of soft-tissue calcification around the hip joint. The medial inferior portion of the head, involving a good amount of the weight-bearing portion, has been removed. There is no evidence of avascular necrosis in the remaining portion of the head and the joint space is normal. At this time, the patient stated that he had too much pain to continue his work as a hod carrier.

good, but traumatic arthritis developed at eighteen months and the result was rated *fair*.

In all five hips with good results after Type V lesions, the inferior medial one-fourth to one-third of the head was removed (Figs. 11-A, 11-B, and 11-C). In none of these hips was there significant damage to the weight-bearing portion of the head. In one of the hips with a good result, there was a transcervical fracture of the femoral neck (Figs. 12-A, 12-B, and 12-C). At open reduction of the dislocation, some small fragments were removed from the inferior portion of the head and two Moore pins were inserted to fix the neck fracture. One month later a bone graft was placed across the fracture in the femoral neck and another Moore pin was inserted for additional stability. Eighteen months later the transcervical fracture had healed.

Of the remaining six Type V lesions, one was not recognized because of a poor roentgenogram. Another roentgenogram made six days after injury revealed the dislocation as well as a subcapital fracture of the femoral neck and a fracture in the medial one-third of the head of the femur. Arthrodesis was performed.

Three patients had unsuccessful attempts at closed reduction and then had open reductions. The results were poor in all three. In one (Figs. 13-A, 13-B, and 13-C) closed reduction was accomplished with difficulty and the hip was opened to remove the fragment of the femoral head which included the medial one-half of the weight-bearing portion. This resulted in a painful hip and a poor result. In the second patient with a poor result the hip joint was opened through a Smith-Petersen approach two months after injury; and a fragment, two by two by three centimeters, which had been avulsed from the anterior aspect of the head, was removed. The fragment was found to be rotated 180 degrees and the bed from which it had been avulsed was in contact with the articular surface of the acetabulum after the fracture-dislocation of the hip was reduced. Avascular necrosis was evident seven months after injury and five months after operation. In the remaining patient the hip was opened, using a Smith-Petersen approach,

ten days after injury. A large fragment was removed which included approximately one-third of the superior articular surface of the femoral head and the attachment of the ligamentum teres. Despite a roentgenographic rating of *good*, this patient had a moderate amount of pain on weight-bearing and moderate restriction of motion; the result was rated *poor*. Hip fusion was performed seventeen months after injury.

FIG. 14-A

Figs. 14-A, 14-B, and 14-C: J.C., a man, seventy-three years old, was hit by an automobile and sustained a Type V dislocation of the right hip; the neck of the femur fractured during attempted closed reduction. At follow-up, four months after injury, the result was rated *poor*.

Fig. 14-A: A roentgenogram made on June 22, 1957, shortly after injury, shows a fragment of the femoral head in the acetabulum. There is no evidence of a femoral-neck fracture.

FIG. 14-B FIG. 14-C

Fig. 14-B: Roentgenogram made later the same day. The patient had been taken to the operating room on the day of injury for primary open reduction of the hip. However, there was a surgical accident and he aspirated fluid into the lungs. Surgery was cancelled, but at a gentle attempt at closed reduction, the neck of the femur fractured.

Fig. 14-C: An Austin Moore prosthesis was inserted one week after injury. This roentgenogram, made on October 29, 1957, four months after injury, shows a moderate amount of calcification about the hip joint. The patient walked well, using a cane.

The last two patients in this group were treated by closed methods. In both the results were poor. In one, a man, seventy-three years old, the femoral neck was fractured during attempted closed reduction; a hip prosthesis was inserted one week later with a satisfactory functional result (Figs. 14-A, 14-B, and 14-C).

DISCUSSION

Surgical treatment of posterior fracture-dislocations of the hip in this series resulted in removal from the joint of many fragments of bone and cartilage which were not demonstrable by roentgenograms. When reduction is performed and these fragments are allowed to remain in the joint, traumatic arthritis rapidly ensues. I believe that open reduction will delay the appearance of such changes and minimize their severity. When an open operation is performed for acetabular fractures, adequate exploration of the joint is impossible without redislocation of the head if the dislocation has previously been reduced by closed manipulation. The additional trauma of closed reduction and redislocation are contra-indications to closed reduction in cases where an open procedure is planned. No difference in the end result could be discerned in this series in patients treated by early open reduction as compared with those treated by open reduction more than twenty-four hours after injury. Of the seventeen primary open reductions done within twenty-four hours, fourteen had good results. In the six patients with dislocated hips reduced by open procedures three to seventeen days after injury, four had good results.

From the results obtained in this series, it is evident that primary reduction produces better results than open operation done after closed reduction. In twenty-three primary open reductions the results were good in seventeen, fair in four, and poor in two. The two poor results were so classified because of an operative death and a surgical infection. In eleven patients who had closed reductions and then open operations more than twenty-four hours after injury there were only five good results.

In the closed reductions, delayed reduction led to poorer results in this series, just as it did in the previous series. Twelve of the sixteen closed reductions were performed less than twenty-four hours after injury with three good results; four were carried out more than twenty-four hours after injury and all four had poor results.

Although the majority of dislocations with the best results in this series were reduced less than twenty-four hours after injury, this does not necessarily imply, and certainly it does not establish as fact, that late reduction is necessarily doomed to failure. In the absence of a comparable series of dislocations treated after twenty-four hours, no conclusion of this sort can be drawn either from the several large series previously reported or from this one. Four of the good results following primary open reductions more than twenty-four hours after injury occurred in patients in whom reduction was delayed for three, five, nine, and thirteen days, respectively. Perhaps it remains for further experience to establish whether or not it is essential to do a closed reduction within twenty-four hours, as Knight and Smith indicated.

Review of the results in Type III fracture-dislocations treated by closed methods in the two series (twenty-eight between 1928 and 1949 and twelve between 1950 and 1957) showed the following. Only one good result was obtained by closed reduction. In the six primary open reductions, good results occurred in five, whereas in five secondary open procedures, there were four good results. These results speak for early surgical intervention in this type of injury with removal of the loose fragments from the joint.

This series does not include acetabular fractures with central protrusion. However, in the Type IV injuries with extensive comminution of the acetabular fragments and posterior dislocation, the extensive comminution of the acetabulum usually did not permit operative restoration of the acetabulum; and the surgical

procedure was limited to removal of the loose pieces of bone, reduction of the dislocation, and fixation of the posterior lip for stability. In these hips, a relatively normal acetabular-femoral head relationship was possible and the results were similar in the small number of cases in which primary open reduction was performed to those obtained in the cases with delayed open reduction. It is noteworthy that closed reduction in this type of fracture-dislocation led to good results in only two cases.

The high percentage of good results in Type V injuries after open operation merits emphasis. Reduction of the dislocation with removal of the loose fragments delays the appearance of traumatic arthritis. However, open reduction where a significant portion of the weight-bearing surface of the femoral head has been fragmented will not give a favorable result if this fragment is removed. Some other therapeutic approach in this type of case must be found.

SUMMARY

A survey of 204 cases of traumatic fracture-dislocation of the hip, covering a period of twenty-one years, was published in 1951. In this series the dislocations and fracture-dislocations were divided into five types. Excellent results occurred only in Type I injuries, the simple dislocations without fracture.

Because of the unsatisfactory results that followed treatment in the fracture-dislocations, Types II, III, IV, and V, a different approach to these serious injuries was considered.

In certain instances there was reason to believe that there were loose fragments within the joint, many of which were not visualized by roentgenogram. Therefore, open reduction was advised in these fracture-dislocations, with the hope that removal of loose fragments and stabilization of an unstable hip joint could delay the appearance of traumatic arthritis and minimize its severity.

In this new series, fifty-five fracture-dislocations had adequate follow-up. Sixteen were treated by closed manipulation and thirty-nine by open reduction. Primary open reduction was performed in twenty-three cases. A comparison of the 1951 survey and the present series would seem to indicate that the results after primary open reductions are superior.

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Axial Fixation of Forearm Fractures*

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The treatment of fractures of the shafts of the forearm bones in the adult is difficult and the results are often disappointing. Knight and Purvis, in 1949, analyzed 100 cases of fresh fractures of the shafts of both bones of the forearm and found a high incidence of unsatisfactory results regardless of the method of treatment. Conservative treatment failed in 71 per cent of the fractures; open reduction without rigid fixation, in 85 per cent; open reduction with plating, in 65 per cent; primary bone-grafting, in 40 per cent; and intramedullary fixation, in 55 per cent. Hughston, in 1957, reported poor results in a series of fractures of the distal radial shaft. Conservative treatment failed in 92 per cent of the fractures; early open reduction and internal fixation produced considerably better results but, even then, failure occurred in 28 per cent.

Fractures of one or both bones of the forearm are difficult to treat because angulatory and rotational stresses on the forearm cannot be eliminated, and these stresses frequently displace the fractures after a satisfactory reduction has been achieved. Delayed union and non-union are frequently unavoidable. For a satisfactory result, it is imperative to splint bones rigidly in anatomical alignment.

Most fracture surgeons [2,4,8,12,15,17] agree that only an occasional transverse fracture in the middle or lower part of the forearm of an adult is amenable to conservative therapy. Evans [5,6,7] has been the outstanding exception, reporting good results with conservative treatment when meticulous attention was given to rotational alignment of the fragments. In the United States these results have never been duplicated. Knight and Purvis concluded that fractures of the upper third of the forearm, and oblique or comminuted fractures at any level in the forearm, are best treated by open reduction and rigid internal fixation of both bones. Hughston also concluded that fractures of the distal third of the radial shaft are difficult to treat successfully by closed reduction. He said that the early treatment of choice is open operation and anatomical reduction with rigid and secure internal fixation. Stewart, in 1958, also advised open reduction and internal fixation for these fractures.

In the adult, internal fixation, despite its obvious hazards, is superior to external fixation alone and should be applied promptly. The intramedullary rod has consistently gained in popularity as the method of choice for internal fixation. However, because of its S-shape, the radius has presented obstacles to medullary nailing.

Smith and Sage, in 1957, analyzed a large series of forearm fractures (555) collected from seventeen different sources. An analysis of treatment of 416 fractures by medullary fixation showed non-union in 21 per cent (eighty-nine fractures). When the fractures treated by intramedullary Kirschner wires were eliminated, the rate of non-union was 14 per cent.

Thus, medullary nailing, which had given brilliant results in the femur and tibia, was initially disappointing in the radius. As a matter of fact, Böhler and Böhler, who originally advocated intramedullary nailing for fractures of the

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forearm bones, declared, in 1949, that they no longer used this method for these fractures. Palmer [21], in 1950, also noted that intramedullary nailing presented many problems and stated that he had more technical difficulties with it than with any other method. Sage, in a meticulous study, reconstructed the medullary canal of the radius and devised a prebent nail to fit this canal. His results were most satisfactory; in eighty-one fractures treated with the prebent nail there was delayed union in only 4.9 per cent and non-union in 6.2 per cent. The results with Sage's method are certainly superior to any previously reported.

In 1954, after vom Saal [20,21] suggested the use of resilient, square, straight clavicle nails in fractures of the forearm, I started to use these nails since I had had disappointing results with single and multiple Kirschner wires and Steinmann pins. The series of fractures being reported on at this time has been accumulated during the past six years. The technique of insertion of the nails has now become standard on our service and is similar to Thompson's method, mentioned by him as having also been used at Walter Reed Army Hospital, utilizing different nails.

FIG. 1

A square nail is superimposed on the radius to demonstrate positioning of the nail.

TECHNIQUE OF OPERATION

The operative procedure is carried out with a tourniquet to control bleeding. The fracture of the radius is exposed, but great care is taken to strip as little as possible periosteum and soft tissue from the bone. A second longitudinal incision is then made in the dorsum of the forearm above the bone prominence of Lister's tubercle, which separates the grooves for the tendons of the radial extensors of the wrist and the long extensor of the thumb; at this level the bone forms a plateau which is readily accessible (Fig. 1). This area is also well above the distal radial epiphysis, and I have not hesitated to use this technique in adolescent children in the rare instances when internal fixation was necessary. Needless to say, open reduction and internal fixation is practically never necessary in children.

A hole is drilled in the radius with particular care to bevel the opening distally so that the nail can be inserted as nearly parallel to the long axis of the radius as feasible. The nails are available in sizes ranging from seven to eleven inches in length and two, three, or four millimeters in width (Fig. 2). The narrow pins are more flexible than the thicker nails, but all have a definite resiliency. Their ends are blunted to minimize the danger of perforation of the cortex.

Since a snug fit is, of course, important, nails with the largest diameter possible are used. In some patients, particularly adolescents, the medullary canal is extremely narrow somewhat distal to the middle of the shaft. Occasionally, it has been necessary to ream out the bone at this level; this can usually be easily accomplished with a drill. The pin is driven in until its tip is at the level of the fracture; the fracture is then reduced under direct vision and the nail is driven across the fracture into the proximal fragment. The flexibility of the straight nail allows restoration of the bow of the radius. Extreme care must be taken to reduce

the radial fragments into anatomical alignment, with particular reference to any rotatory displacement. For stability, the rod should penetrate the proximal fragment for several inches; this sometimes makes it imperative to push the nail up to the region of the neck of the radius. The square shape of these nails prevents rotatory deformity, as well as angulation, and gives good stability. This has been convincingly demonstrated in the operating room time and again. The insertion of the nail through the dorsum of the distal shaft of the radius, rather than through the radial styloid process, allows the insertion of a straight pin (Fig. 1). The difficulties presented by the S-shape of the radius, for which Sage recently constructed such an elaborate set of nails, are thus overcome for the most part.

The fracture of the ulna is next exposed and, through a second incision over the tip of the olecranon, a suitable nail is introduced and driven to the distal end of the ulna. Again the nail is first advanced only to the fracture site, then the fracture is reduced under direct vision and the nail is driven into the distal fragment as far as practical. In adolescents the epiphyses can be avoided if the nail is introduced through the subcutaneous surface of the ulna distal to the olecranon. Of course, care should also be taken not to disturb the distal epiphysis of this bone.

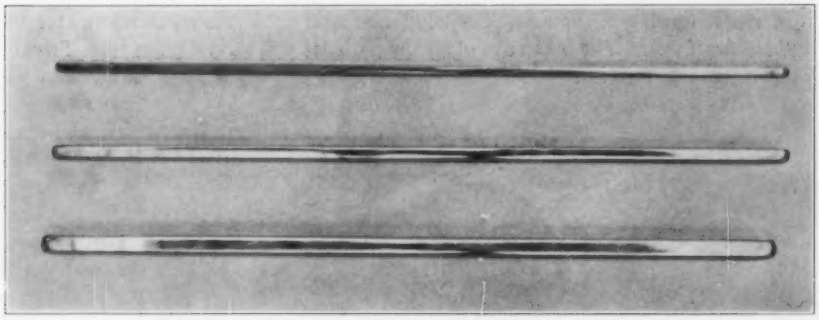

FIG. 2

The square, resilient nails.

The adequacy of the reduction and the position of the nails are then checked by roentgenogram. The tourniquet is released as soon as internal fixation is completed. After hemostasis, the incisions are closed and a long arm cast applied. Some care is given to the position of the forearm, but the minute adjustments of the position of the radius, as recommended by Evans [7], are not necessary. I favor keeping the forearm in supination for fractures of the upper portion of the radius; in mid-position for fractures in the middle of the radius; and in full pronation for fractures in the lower portion of the shaft of this bone. The long arm cast must extend from the axilla to the distal palmar crease to give firm external fixation.

Two weeks after operation the cast is changed, the sutures are removed, and healing of the fracture is followed by serial roentgenograms. Healing is evaluated clinically and roentgenographically after approximately two months. External fixation is continued until firm union is obtained. In this series it has been difficult to determine when union is sufficiently firm to discontinue external immobilization, since roentgenographic evidence of trabeculae extending across the fracture site is a late sign [11]. I am guided by the clinical signs, particularly absence of both local tenderness and pain, when the fracture site is strained. Particular attention, both clinically and roentgenographically, has been directed to the maintenance of alignment of the fragments and to the maintenance of position of the intramedul-

lary pins. Bone absorption about the ends of the nails is also carefully looked for. Stimulated by the observations of Trueta and Cavadias, I have looked for evidence of subperiosteal bone formation in association with intramedullary rods but have been unable to confirm their experimental findings in my clinical material. The scaffolding callus is usually quite sparse but it becomes manifest much earlier than bone trabeculae across the fracture site. I do not think that these fractures need external immobilization until massive callus is present, if all the other signs point to union. Function of the extremity is encouraged immediately after operation, and most patients need little formal physiotherapy after removal of the cast.

MATERIAL

The patients in this report were treated at Lincoln Hospital, a large city hospital serving a poor neighborhood in New York. The series includes all unstable fractures of the forearm in adults since 1954 and unstable fractures in two adolescents and two young adults under nineteen. In my experience, these fractures are quite uncommon, only thirty-five having been collected in six years on a large, active accident service. These fractures occurred in twenty-three male and twelve female patients, ranging in age from twelve to seventy-five years. Four patients were under twenty at the time of injury; their ages were twelve, thirteen, sixteen, and eighteen years. The mean age of all the patients was forty-three years. Twenty patients had fractures of both bones of the forearm, eleven had fractures of the shaft of the radius alone, one had a fracture of the ulna only, one patient had fractures of the distal third of the ulna and the head of the radius, one had fractures of the radius at the junction of the middle and distal thirds and of the distal extremity of the ulna, and one had a flexion-type Monteggia fracture. Seven fractures were open and twenty-eight were closed. Twenty-two fractures involved the middle of the shafts; nine, the distal; and four, the proximal thirds of the bones. Nineteen fractures involved the right forearm and sixteen the left.

MODE OF ACCIDENT

Sixteen patients were injured in vehicular accidents, thirteen were injured in jumps or falls, five were assaulted and injured by a weapon, and one was injured in an industrial accident in which his forearm was caught in a rotating belt.

ASSOCIATED INJURIES

Ten patients had cerebral concussion, four patients had other fractures of the upper extremities. Two of these four had extremely severe injuries involving the entire upper extremity: one was sideswiped by a car and had a fracture of the humerus, open fractures of the distal third of the ulna and the head of the radius, and fractures of all the metacarpals and proximal phalanges; the other patient had fracture-dislocations of the elbow and wrist, extensive lacerations, and open fractures of the mid-shafts of the radius and ulna. This patient also had a cerebral concussion and fractures of the seventh, eighth, and ninth ribs on the same side. Two patients had fractures of the lower extremities, two had fractures of the pelvis, two had multiple rib fractures, and one had a solitary rib fracture. One patient had extensive severance of flexor tendons.

TREATMENT

All patients were admitted to the surgical service of the hospital and had one or more attempts at closed reduction followed by immobilization in long arm casts. Wound débridement of the open fractures was performed on the day of admission. All of these patients were transferred to the orthopaedic service

because the position of the fragments was unsatisfactory or the fractures were judged to be unstable.

Open reductions were performed under my supervision as soon as feasible. Occasionally, because of associated injuries and poor general condition of the patient, surgical intervention had to be delayed (essentially, however, this study includes only fresh fractures). Definitive operations were performed as early as the day of injury and as late as forty-five days after injury. The mean time elapsed between the accident and open reduction and internal fixation of these fractures was 11.5 days. Open reduction and intramedullary nailing of any fracture should not be considered an emergency procedure and should be done only under optimum conditions.

In seventeen patients both the radius and ulna were fixed internally; in fourteen, only the radius was fixed; and in four, the ulna alone was fixed. Early in the series four patients were treated without immobilization in a cast. Although all four fractures healed, I was not particularly impressed with any advantage accruing from the lack of external immobilization. These patients frequently overprotected their injured extremities and what seemed to be a mild sympathetic dystrophy developed in one. Internal fixation without external immobilization is not recommended. Another patient, whose fracture was initially treated without external fixation, was observed thirteen days after operation while still in the hospital to be lifting himself out of bed with the fractured forearm. Some splintering of the fracture fragments was demonstrated after this episode. His upper extremity was immobilized in a long arm cast immediately, and the fracture healed uneventfully.

RESULTS

Follow-up of these patients was fraught with the usual difficulties encountered in a city hospital in a poor neighborhood, but fortunately only three were lost and they had been observed for a sufficient length of time to make sure that their immediate postoperative convalescence was uneventful (forty-one, twenty-seven, and thirteen days, respectively).

In this series a fracture was classified as *united* when there was no tenderness at the fracture site, when stress on the fracture elicited no pain, and when the roentgenograms showed haziness at the fracture site, with the fragments and the nails maintained in the original alignment; usually some scaffolding callus was present at this time, but bone trabeculation across the fracture was not considered necessary for this clinical union. Of the thirty-two patients whose fractures were classified as *united*, the shortest follow-up was two months and the longest fifty-nine months, with a mean of 10.4 months; eight patients were followed for over a year. In the four patients whose fractures were treated without external fixation, union occurred in three to six months, an average of five months. In the remaining patients whose fractures were treated by combined internal and external fixation, healing occurred in from six weeks to nine months, the average being three and three-quarters months. The patient whose fractures united in about six weeks was a young adult of eighteen who was assaulted on June 24, 1958, and had sustained closed, almost transverse, serrated fractures of the midshafts of both radius and ulna. Operation was carried out on July 2, 1958, and both bones were internally fixed. The plaster cast was removed on August 12, 1958, when the fractures were judged to show clinical union.

Union of fractures treated with combined internal and external fixation, as defined in this study, occurred at or before two months in eleven patients, between two and four months in twelve patients, and after four months in four patients.

There was little significant difference between the healing time of the open fractures and that of the closed fractures. Most of the open fractures were not accompanied by extensively lacerated wounds. The open fractures healed in an average of four months, whereas the closed fractures healed in an average of 3.5 months.

The anatomical results were graded on the basis of alignment, as shown by roentgenogram, as *excellent*, *good*, and *poor*.

In an excellent result, there was anatomical alignment of the fragments.

In a good result, there was slight step formation or angulation not exceeding 10 degrees, but no rotational deformity. Somewhat exuberant callus formation was present in some fractures.

In a poor result, there was synostosis at the fracture site.

There never was angulation exceeding 10 degrees and there were no cases of non-union.

The functional results after fractures of the forearm are, of course, of prime importance. In this study the functional result was rated as *excellent* if there was at least 90 per cent of rotation of the forearm and 90 per cent of motion of the shoulder, elbow, wrist, and fingers of the hand.

TABLE I

THIRTY-TWO FRACTURES OF THE FOREARM

	Excellent	Good	Poor
		Anatomical Results	
Radius only	7	4	0
Radius and ulna	9	5	4
Miscellaneous group	1	2	0
		Functional Results	
Radius only	9	2	0
Radius and ulna	9	4	5
Miscellaneous group	0	3	0

The functional result was rated as *good* if there was from 70 to 90 per cent of normal rotation of the forearm and similar motion of the other joints of the upper extremity.

The result was rated as *poor* if there was less than 70 per cent of motion of the forearm or other joints of the extremity.

Of the thirty-two fractures, there were twenty-eight excellent and good results and four poor results on an anatomical basis. On a functional basis, there were twenty-seven excellent and good results and five poor results (Table I).

COMPLICATIONS

Radio-ulnar synostoses developed in three patients. All had fractures of the radius and ulna at approximately the same level and in each instance the fracture was the result of severe trauma: automobile accidents in two and a fall from a fifth-story window in the other. The forearms of two of these patients were fixed in mid-position, whereas the third patient had 15 degrees of supination and 10 degrees of pronation. When last seen this patient continued to work as a clothes designer. All three patients refused further surgical intervention. A rupture of the extensor pollicis longus tendon developed in one patient but he refused to have this repaired.

In one patient with a fracture of the proximal third of the radius a transient motor paralysis of the posterior interosseous nerve developed after the fracture had been exposed through an anterior Henry incision. In another patient, as the

TABLE II

FRACTURES OF THE SHAFT OF THE RADIUS
ELEVEN CASES

Case, Sex, and Age	Type of Injury and Date	Site and Type of Fracture	Associated Injuries and Disease	Date of Operation	Duration of External Immobilization (*Weeks*)	Time to Union (*Weeks*)	Follow-up (*Months*)	Complications	Results	
									Anatomical	Functional
L.H. M 44	Car 4–5–54	9 cms. above wrist Closed, short oblique	Fracture, ulnar styloid	4–29–54	0	20	8	None	Excellent	Excellent
E.N. M 44	Fall 1–1–55	Upper mid-third Closed, comminuted, short oblique	Cerebral concussion, pneumonia, delirium tremens	1–19–55	37	37	18	None	Excellent	Excellent
A.M. F 36	Car 3–8–56	Mid-shaft Closed, transverse	Cerebral concussion	3–28–56	0	18	10	None	Excellent	Good
H.M. M 60	Car 4–1–56	10 cms. above wrist Closed, comminuted, transverse	Fracture, 7, 8, and 9th ribs Fracture of pelvis and ankle	4–11–56	0	22	14	None	Excellent	Excellent
R.S. M 43	Fall 7–5–57	Upper third Closed, L-shaped	None	7–17–57	10	10	17	Transient posterior interosseous palsy	Excellent	Excellent
S.K. M 69	Car 9–15–57	7 cms. above wrist Closed, comminuted, short oblique	Fracture of pelvis	9–25–57	15	15	21	None	Good	Excellent
J.P. M 70	Car 9–15–58	9 cms. above wrist Open, short oblique	Open fractures of tibia and fibula Hemiplegia ('58)	9–25–58	None	14	4	None	Good	Good
R.A. M 32	Fall 3–1–59	9 cms. above wrist Closed transverse	None	3–6–59	10	10	2½	None	Excellent	Excellent
E.D. F 58	Fall 5–26–59	8 cms. above wrist Closed, short oblique	None	5–29–59	15	15	5	None	Good	Excellent
H.C. M 74	Bicycle 10–10–59	9 cms. below elbow Closed, comminuted, short oblique	None	10–21–59	5	5	6½	None	Good	Excellent
L.G. M 30	Assault 10–23–60	6 cms. above wrist	None	10–25–60	7	7	3	None	Excellent	Excellent

TABLE III

FRACTURES OF THE RADIUS AND ULNA
TWENTY CASES

Case, Sex, and Age	Type of Injury and Date	Site and Type of Fracture	Associated Injuries and Disease	Date of Operation	Duration of External Immobilization (*Weeks*)	Time to Union (*Weeks*)	Follow-up (*Months*)	Complications	Results Anatomical	Results Functional
E.B. M 50	Car 2-4-54	Closed, comminuted Segmental	Fractures of humerus and pubis	2-10-54	34	34	59	Synostosis	Poor	Poor
A.Y. F 13	Fall 1-2-55	Mid-shaft Closed, transverse	None	1-21-55	8	8	50	Radial nail missed proximal end of distal fragment	Poor	Poor
J.M. M 64	Car 1-13-56	Mid-shaft Closed, short oblique	Rupture of extensor pollicis longus	1-25-56	9	9	28	Synostosis	Poor	Poor
L.A. F 46	Assault 5-20-56	Mid-shaft Closed, short oblique	None	5-23-56	?	?	Lost after 4 wks.			
M.S. M 30	Fall 9-23-56	Mid-shaft Closed, transverse	None	10-3-56	16	16	9	None	Excellent	Excellent
U.McL. F 62	Car 12-22-56	9 cms. above wrist Open, transverse	None	1-9-57	9	33	34	Ulnar nail extruded, removed 4-3-58 Sympathetic dystrophy?	Excellent	Excellent
A.P. F 33	Fall 11-23-57	Mid-ulna: 7 cms. above wrist Closed, short oblique	None	11-27-57	9	9	18	Prominent radial nail, patient refused treatment	Excellent	Excellent
J.C. M 18	Assault 6-29-58	Mid-shaft Closed, transverse	None	7-2-58	6	6	2½	None	Excellent	Excellent
A.G. M 27	Assault 10-19-58	Radius: 7 cms. below elbow Ulna: mid-shaft Closed, short oblique	None	10-29-58	27	27	7½	Ulnar nail extruded; removed, 4-1-59	Good	Good
G.D. M 16	Fall 2-27-59	6 cms. above wrist Open, transverse	None	3-25-59*	7	7	8	None	Good	Good

P.A. F 48	Car 6–23–59	5 cms. above wrist Closed, short oblique	None	6–24–59†	17	17	10	None	Good	Good
A.C. M 52	Fall 6–27–59	Radius: 7 cms. above wrist Ulna: 4 cms. above wrist Closed, comminuted	None	6–28–59	21	21	5	None	Excellent	Excellent
J.S. M 12	Fall 9–25–59	Mid-shaft Ulna: closed, short oblique Radius: transverse	None	9–30–59	9	9	3	None	Excellent	Excellent
J.W. M 27	Indus-trial 1–8–59	Radius: 8 cms. above wrist Ulna: greenstick Open, oblique	None	1–14–59	14	14	7	None	Excellent	Excellent
V.R. M 42	Fall 12–22–59	8 cms. above wrist Closed, transverse	None	12–30–59	8	8	4	None	Excellent	Excellent
T.C. F 61	Car 1–21–60	Mid-shaft Closed, transverse very comminuted	Cerebral concussion, fracture of fifth metacarpal	2–3–60	10	10	13	Frozen shoulder	Good	Good
L.G. F 22	Fall (five stories) 5–22–60	Mid-shaft Closed, trans-verse, extremely comminuted	Severe cerebral concussion	6–8–60	17	17	4	Synostosis	Poor	Poor
T.B. M 60	Car 6–4–60	Mid-shaft Closed, com-minuted	Cerebral concussion	6–15–60	14	14	9	None	Excellent	Excellent
J.C. M 30	Car 7–10–60	7 cms. above wrist Open transverse, very comminuted	Severed flexor tendons	7–10–60 (ulna) 8–2–60 (radius)	10 7	10 7	5	None	Good	Poor
W.W. M 35	Fall (four stories) 7–30–60	Radius: 12 cms. above wrist Ulna: 5 cms. above wrist	Cerebral concus-sion; fracture-dislocation of elbow and wrist; fractures 7, 8, and 9th ribs	8–25–60	Lost	?	2 wks.	?	?	?

* Radius fairly well aligned; ulna was nailed. † Radius only nailed.

TABLE IV

MISCELLANEOUS FOREARM FRACTURES

FOUR CASES

Case, Sex, and Age	Type of Injury and Date	Site and Type of Fracture	Associated Injuries and Disease	Date of Operation	Duration of External Immobilization (*Weeks*)	Time to Union (*Weeks*)	Follow-up (*Months*)	Complications	Results	
									Anatomical	Functional
C.R. F 59	Fall 2–28–56	Ulna: 5 cms. below olecranon Radius: posterior dislocation of head	None	3–21–56*	11	11	3	Head of radius excised	Good	Good
S.E. M 75	Car 9–20–56	Radius: 9 cms. above wrist Ulna: distal shaft; open	None	10–3–56	16	16	12	Proximal fragment of radius missed, reoperation 2 wks. later	Good	Good
L.S. M 36	Car 10–5–58	Ulna: distal shaft; open Radius: fracture of head	Extensive lacerations; fractures of the humerus and all metacarpals, proximal phalanges, same side	11–11–58			Lost after 6 wks.		?	?
L.Y. F 33	Assault	Ulna: 9 cms. below olecranon Closed, short oblique	Fracture of the 8th rib	12–9–59	9	9	2½		Excellent	Good

* Ulna only nailed; head of radius excised.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 1. Original roentgenogram made on January 2, 1955.
Fig. 3-B: After removal of the cast, March 21, 1955.

result of a technical error, the proximal fragment of the radius was missed by the nail; this was corrected by a second operation. Frozen-shoulder syndrome developed in four patients, whose ages were fifty, sixty-one, sixty-two, and fifty-four years, respectively. Hypesthesia of the dorsum of the hand, confined to the region of the second metacarpal, also developed in four patients (Tables I, II, III, and IV).

All nails were left *in situ* except for two in the ulna and one in the radius. These nails migrated proximally in the ulna and distally in the radius; they were removed five, five, and fifteen months after operation respectively. No broken or severely bent nails were encountered, but some bend in the nail in the radius occurred in practically all patients.

There were no deaths and no infections.

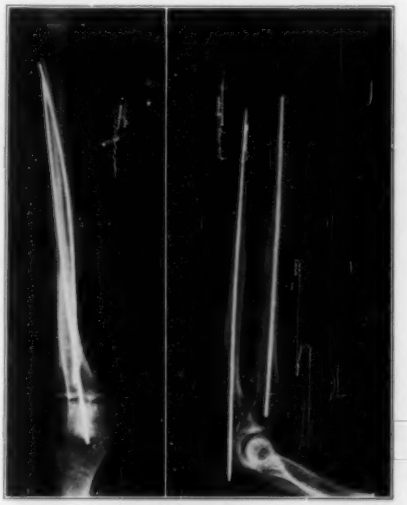

FIG. 3-C
End result, May 13, 1959.

CASE REPORTS

CASE 1. A.T., a thirteen-year-old girl (Figs. 3-A, 3-B, and 3-C), sustained almost transverse, displaced, closed fractures of both bones of the left forearm when she fell on the street on January 2, 1955. A long arm cast was applied. The ulnar fracture was about one centimeter distal to the radial fracture. The fragments were angulated forward, and the distal shaft of the ulna was displaced backward. Closed reduction was not satisfactory, and on January 21, 1955 (nineteen days after injury), open reduction and internal fixation of both bones was done. The medullary canal of the radius was exceedingly narrow at one point and allowed passage of only a two-millimeter nail. Good alignment and excellent fixation of the ulna were obtained, but a small degree of rotation could be demonstrated at the fracture site of the radius. The alignment of the radius generally was good. A long arm cast was applied which was removed on March 21, 1955, two months after

operation. The patient was last seen on May 13, 1959, over four years after the accident. Slight volar bowing of the radius was noted at that time, but in general the alignment of the forearm was good. Supination was restricted to 30 degrees, pronation to 90 degrees, and dorsiflexion of the right wrist was 70 degrees (90 degrees on the opposite side); other wrist motions were 90 per cent of normal. Shoulder, elbow, and finger motions were free. There was a small area of hypesthesia over the dorsum of the forearm, medial to the distal radial incision. Strength of the hand and the entire left upper extremity was normal. Roentgenographic examination of the forearm revealed solid bone union of the fractures in good alignment, with slight volar bowing of the radius.

Comment: This was considered a poor result. Looking back over the whole series of roentgenograms, it would appear that the rod penetrated the dorsal cortex of the proximal end of the distal radial fragment; this would account for the volar bowing. The patient was satisfied with the result.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 2. Roentgenogram made on March 30, 1956, two months after open reduction and nailing.
Fig. 4-B: End result, May 13, 1958.

CASE 2. V.M., a man, sixty-four years old (Figs. 4-A and 4-B), fell asleep while driving on January 13, 1956, and his car smashed into a stanchion of the Triborough Bridge. He sustained closed, comminuted, oblique, displaced fractures of the mid-shafts of both bones of the right forearm. The ulnar fracture was two centimeters distal to the radial fracture. Initial closed reduction was unsatisfactory. On January 25, 1956, twelve days after the accident, open reduction was done and both fractures were fixed with square nails. On March 30, 1956, the fractures were judged to be solid and the cast was removed. The patient was last seen on May 13, 1958; he had continued to work as a riding-clothes designer. The fractures were solid and in good alignment, but there was extensive synostosis. Shoulder and elbow motions were free, pronation was possible to 10 degrees and supination to 15 degrees; wrist motions were 90 per cent of normal. There was a rupture of the extensor pollicis longus tendon with drooping of the terminal phalanx of the right thumb.

Comment: This was classified as a *poor* result. I do not think that the operation *per se* was responsible for the synostosis since this patient had sustained an extremely severe injury. The rupture of the long extensor tendon of the thumb was probably due to the jagged distal end of the radial nail which was cut off at operation. From that time on great care has been taken to measure pins accurately

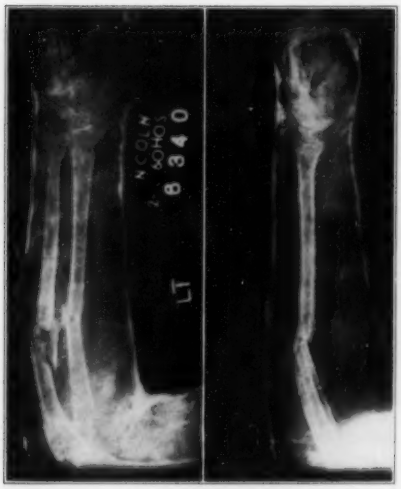

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 4. Roentgenogram made on February 2, 1960, shortly after closed reduction.
Fig. 5-B: Roentgenogram made on March 1, 1960, approximately one month after open reduction and nailing.
Fig. 5-C: Advanced consolidation has taken place by November 1, 1960.

and to have a sufficient assortment of pins available to permit selection of the exact size, as far as length and width are concerned. The patient was satisfied with the result and continued to work as a clothes designer; he refused removal of the internal fixation device, excision of the synostosis, or repair of the thumb tendon.

FIG. 5-C

CASE 3. E.B., a man, fifty years old, was knocked down by an automobile and sustained a cerebral concussion and fractures of the neck of the right humerus and of the right pubis on February 3, 1954. He also had a sprain fracture of the internal ligament of the right knee. He sustained closed, comminuted segmental (double) fractures at the junction of the middle and distal thirds of the right radius and ulna. Original closed reduction was unsatisfactory; open reduction and internal fixation of both bones with intramedullary nails was performed on February 10, 1954, one week after the accident. The nails were removed on July 21, 1954, and the patient continued with external fixation until October 7, 1954, eight months after the injury. A severe frozen-shoulder syndrome and synostosis between the bones of the forearm developed. When the patient was last seen on January 20, 1959, the shoulder had recovered. Elbow motions were 180 to 40 degrees, the forearm was fixed in mid-position, wrist motions were about 70 per cent of normal, and finger motions were free. He had returned to work as a pullman porter in June 1956.

Comment: This patient had exceedingly severe injuries to the entire right side of the body. Although the fractures of the radius and ulna healed promptly, the result in this patient is classified as *poor*.

Case 4. T.C., a woman, sixty-one years old (Figs. 5-A, 5-B, and 5-C), was struck by a motorcycle on January 21, 1960, and sustained a cerebral concussion, lacerations of the left eyebrow, and fracture of the neck of the fifth metacarpal of the left hand. In addition, she had slightly comminuted fractures of the radius and ulna at about the same level, ten centimeters below the head of the radius. Initial care consisted in application of a plaster-of-Paris long arm cast. Open reduction and internal fixation of both bones was done on February 3, 1960. The fractures were judged clinically solid on April 15, 1960, and the cast was removed. Solid union occurred, as seen by roentgenogram, but there was slight angulation of both bones. Synostosis fortunately did not develop. The patient was last seen on November 22, 1960, some ten months after injury. A frozen-shoulder syndrome, which had developed, was receding. Elbow, wrist, and finger motions were complete. Supination of the forearm was possible to 50 degrees and pronation to 60 degrees.

Comment: This patient is judged to have a poor result. In retrospect, a larger-caliber pin should have been used.

Case 5. L.G., a woman, twenty-two years old, fell out of a fifth-story window on May 22, 1960, and sustained a severe cerebral injury. She also had closed, severely comminuted fractures of the mid-shafts of the right radius and ulna which were unstable. Because of the poor general condition, open reduction was delayed until June 8, 1960, when both bones were pinned. At the time of operation there was already definite synostosis between both bones and a note was made at the time that the prognosis for rotation of the forearm was poor. The patient had an uneventful convalescence and the fractures were judged to be solid on October 11, 1960, four months after operation. The patient regained good function of the extremity with almost normal joint motions, except for rotation of the forearm which was almost fixed in the neutral position. Synostosis in this instance developed promptly after injury because of the exceedingly severe trauma and comminution.

Fig. 6-A

Fig. 6-B

Fig. 6-A: Case 6. Roentgenogram made on April 3, 1956, two days after fracture.
Fig. 6-B: September 5, 1956, five months later.

Case 6. H.M., a man, sixty-nine years old (Figs. 6-A and 6-B), sustained a closed, transverse fracture of the right radius about ten centimeters above the wrist when he was knocked down by an automobile on April 1, 1956. He also had a severe fracture of the right ankle and a fracture of the pelvis extending into the acetabulum. Closed reduction of the fracture was unsuccessful, and the radius was pinned on April 11, 1956. External fixation was not used. The patient was judged to have solid bone union with good alignment some time before September 5, 1956. All joints retained full motion. The patient was last seen on June 18, 1957, some fourteen months after the accident.

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 7. Roentgenogram made on July 12, 1957, just before open reduction.
Fig. 7-B: The fracture is consolidated on September 24, 1957.

Fig. 8: Case 8. Late result, as seen on May 12, 1959, almost two and one-half years after the accident.

Comment: This was judged a good result of the fracture of the radius.

CASE 7. R.S., a man, forty-three years old (Figs. 7-A and 7-B), fell downstairs on July 5, 1957, and sustained a Z-shaped fracture of the upper third of the left radius. The original reduction seemed satisfactory, but the fracture slipped. Open reduction and internal fixation of the fractured radius was done on July 12, 1957; an anterior Henry incision was used. Excellent alignment and fixation were obtained. A transient paralysis of the posterior interosseous nerve developed. Complete recovery required almost two years. The fracture itself healed promptly and was judged united by September 22, 1957. The patient eventually had a good result.

FIG. 8

CASE 8. A.B., a woman, thirty-three years old (Fig. 8), fell on the street on November 23, 1957, and sustained closed fractures of the left radius and ulna. The fractures were somewhat oblique, the ulnar fracture being three centimeters distal to the radial fracture. The patient also sustained a laceration of the forearm. Closed reduction was unsatisfactory. Open reduction and internal fixation was performed on November 27, 1957, four days after injury. A long plaster cast was applied; this was removed on January 30, 1958, approximately two months after surgery. The patient was last seen on May 12, 1959, almost two and a half years after the accident. Shoulder and elbow motion were free. Supination was possible to 90 degrees and pronation to 75 degrees; wrist motions were 95 per cent of normal. The radial pin protruded slightly and removal was advised but refused by the patient because of excellent function.

SUMMARY AND CONCLUSIONS

Thirty-five patients with fractures of the shafts of the forearm bones were treated over a six-year period. The results in thirty-two of these patients with fifty fractures were evaluated for study. Treatment of these fractures consisted in early open reduction and internal fixation with square, snug-fitting, somewhat flexible, straight intramedullary nails which were introduced by a simple technique. Five patients were initially treated without external fixation but all other patients were immobilized in long arm casts. All fractures united promptly. There were no infections, no mortality, and few complications. Although this series is small, the results are sufficiently encouraging to recommend further trial.

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Internal Fixation of Fractures of the Forearm

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Recently two conflicting conclusions have been published concerning the use of intramedullary fixation in adults for the treatment of fractures of the shaft of the forearm bones [3,5].

Smith and Sage reported on the results in 555 fractures of the forearm treated in many different ways by seventeen different groups of surgeons. Included in their series were fifty-three fractures of the radius alone, eighty-seven of the ulna only, and, in the both-bone fractures, 206 in the radius and 209 in the ulna. Excluding the fractures treated by intramedullary Kirschner wires (rate of non-union, 38 per cent) there were 321 fractures treated by intramedullary fixation with an over-all incidence of non-union of 14 per cent. These authors concluded that intramedullary fixation is simple and efficient in solitary fractures of the ulna but that it is not simple and not uniformly efficient in fractures of the radius. Sage subsequently reported the development and use of a prebent triangular nail for the radius and a straight triangular nail for the ulna. Using these, he achieved an incidence of delayed union or non-union of 11.1 per cent in eighty-one fractures. He concluded that the prebent triangular nail is indicated in the treatment of diaphyseal fractures of the radius, except in the proximal and distal fourths of the radius, provided that the medullary canal is of adequate size.

In contrast to the conclusions of these authors are those of Jinkins and associates, who reported on 176 forearm fractures (twenty-seven in the radius, nineteen in the ulna, and sixty-five in both bones, or 130 individual fractures). Excluding two cases (four fractures) in which a reconstructive procedure was carried out to restore stability by attempting to make the distal fragment of the radius unite to the proximal fragment of the ulna and excluding seven fractures of both bones in which the ulna was treated closed without any external fixation, these authors treated 165 individual fractures of the radius and ulna singly and of both bones in combination. In these 165 fractures, 145 Eggers' plates and twenty intramedullary rods, with or without bone-grafting, were used. Non-union resulted in six fractures, an incidence of 4.2 per cent. These authors concluded that the best results could be obtained by using a slotted plate on the ulna and either a slotted plate or a Rush pin for the radius.

In our clinic, we have followed 212 fractures of the forearm of which 157 were treated with intramedullary pins, forty with Eggers' slotted plates, and fifteen with four-hole plates. It was hoped that study of these fractures would shed some light on the problem. Open reduction and internal fixation for fractures of the shaft of the forearm in adults was first performed in our clinic twenty years ago and has been our standard treatment for the past ten years. During this time three distinct forms of internal fixation were used. Our first real experience was with four-hole forearm plates, which yielded such poor results that their use was rapidly abandoned. The transition from these plates to slotted plates and to intramedullary pins almost simultaneously was undoubtedly wise. It is interesting to note that Eggers' plates were used cautiously, presumably because of their similarity to the four-hole plates[1]. This caution was manifest by the use of twelve to sixteen weeks of external immobilization. Rush pins, on the other hand, being associated with intramedullary fixation of the femur, were used boldly, occasionally at first

without any external immobilization and later with only four to six weeks of external immobilization. Then, about five years before the time of writing, we began to use Rush pins almost exclusively. This use of Rush pins was no doubt motivated by the technical ease of insertion and the versatility of the pins. However, subsequent experience leaves some doubt as to the wisdom of this change.

CASE MATERIAL

We were able to obtain 127 adults, with a total of 212 fractures of the shafts of the forearm bones, who had been treated by the staff of the clinic and who had adequate roentgenograms and follow-up records. Twenty-six weeks was selected arbitrarily as the outside time limit for union; any fracture not united at this time was declared a non-union. Three distinct types of internal fixation were used: four-hole plates, Eggers' slotted plates, and intramedullary Rush pins.

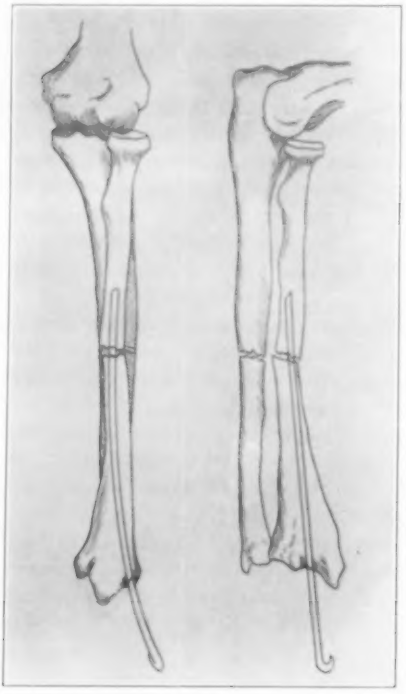

FIG. 1

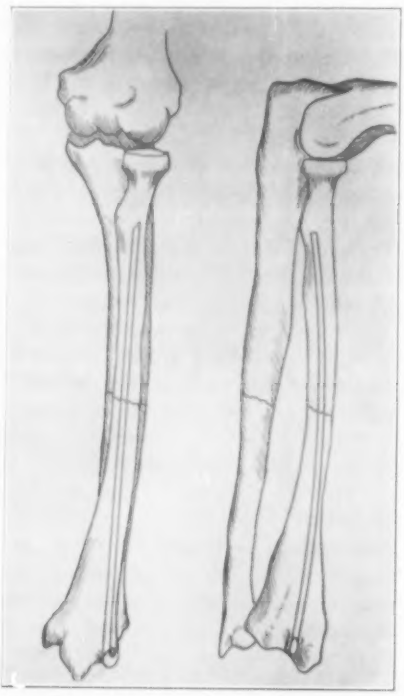

FIG. 2

Fig. 1: Anteroposterior and lateral views of prebent Rush pin inserted at Lister's tubercle and driven past the fracture site.

Fig. 2: Anteroposterior and lateral views after prebent pin has been rotated 90 degrees and tapped into the tubercle.

PROCEDURE

Shortly after use of intramedullary pins was started, the location for the insertion of the pin was changed from the radial styloid process to Lister's tubercle, and the Rush pin was bent into a gradual curve before it was inserted. In the procedure in current use, a hole is drilled for the pin directly on top of Lister's tubercle, which is easily found. Due to its prominence, the tubercle protects the tendon of the extensor pollicis longus from injury. As the pin is inserted, the wrist is acutely flexed. The pin is driven past the open fracture site (Fig. 1), rotated

until alignment is anatomical, and then tapped in as far as the bicipital tubercle (Figs. 2 and 3). This technique markedly simplifies the use of Rush pins in the radius. Although the medullary canal of the radius is a complex of curves, as pointed out by Sage, moving the insertion to Lister's tubercle reduces the curves to be considered to a single dorsolateral curve. This is important because the rotation of a prebent nail 90 degrees will theoretically restore the radial bowing. On the other hand, pins inserted at the styloid process must pass through an S-shaped curve, and, for all practical purposes, the pin is straightened out as it is driven in. Rotation of this relatively straight nail, therefore, frequently has little effect on position of the fracture fragments.

The ulnar fractures were exposed, and a reamer passed retrograde out through the olecranon. The straight Rush pin was inserted at the olecranon and driven past the fracture site. The plates were all applied in a standard manner, subperiosteally, with care to strip as little periosteum as possible. In general, Henry incisions were used to approach the radius[2].

BONE GRAFTS

All bone grafts were autogenous iliac grafts. Of the 157 fractures treated initially with Rush pins, bone-grafting was done in only eighteen (11.5 per cent) and all but two united. There were ten secondary bone-grafting operations for established non-union in which bone grafts were applied to thirteen fractures; all of these fractures united.

EXTERNAL IMMOBILIZATION

Early in this study, the external immobilization employed was a full arm cast which extended from the axilla to the base of the palm and through the web space of the thumb. Later, to encourage hand function, anterior and posterior plaster splints were used, which extended from the axilla to the base of the palm but left the web space of the thumb free. The length of immobilization varied with the type of internal fixation. With four-hole plates, the average duration of external immobilization was eighteen weeks; with slotted plates, 11.9 weeks; and with Rush pins, 6.7 weeks.

COMPLICATIONS

There were five postoperative infections, all following open fractures. One of these infected fractures, which is not included in this series, was a catastrophe. Gas gangrene developed immediately after operation and despite extensive treatment, amputation through the middle one-third of the humerus was required as a lifesaving procedure. The other four infections are included in this series; these wounds healed by secondary intention, with only one sequestrectomy being needed.

The ulnar pin backed out in seven patients. This did not occur with the radial pin. In four of the seven patients the pin protruded through the skin under the plaster cast, with resulting subcutaneous infection at the olecranon. This necessitated premature removal of the pin from two patients with loss of position and alignment (Figs. 4-A and 4-B). In three patients the pins were reinserted. All seven of these patients had delayed union and non-union of the ulna.

The Rush pin broke in three fractures—in both the radius and ulna in one patient with fracture of both bones and in the ulna in another patient with fracture of the ulna alone. It was interesting to note that in the patient with fracture of both bones, the ulnar pin fractured first and then the radial pin (Figs. 5-A, 5-B, and 5-C). All three broken pins were associated with non-union of the fracture.

Synostosis occurred in two patients. In one both bones were fractured but only the ulna was pinned, the radius being treated closed (Fig. 6). The radius angu-

FIG. 3

FIG. 4-A

Fig. 3: Typical solitary fracture of the radius treated with prebent Rush pin inserted at Lister's tubercle.

Fig. 4-A: Roentgenogram sixteen weeks after open Monteggia fracture treated initially by closed reduction of the dislocated radial head and internal fixation of the ulna with a Rush pin. External immobilization was discontinued ten weeks after operation. The Rush pin backed out sixteen weeks after operation and was removed.

FIG. 4-B

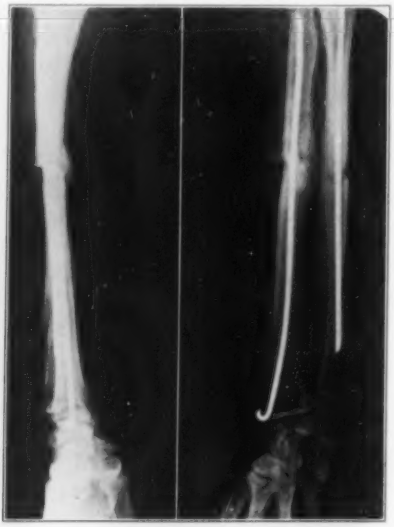

FIG. 5-A

Fig. 4-B: Roentgenogram, five years after fracture, shows the ulna to be solidly united with 30 degrees of angulation and subluxation of the radial head. The forearm was fixed in 12 degrees of pronation. Elbow motion was from 150 degrees to 90 degrees. The forearm was stable; the patient was working regularly.

Fig. 5-A: Roentgenograms made three months after internal fixation of a fracture of both bones of the forearm with Rush pins. Non-union is evident in both radius and ulna. Bone-grafting was recommended and refused at this time.

FIG. 5-B

FIG. 5-C

Fig. 5-B: Roentgenogram six months after operation shows fracture of the pin in the ulna.
Fig. 5-C: Roentgenogram eight months after operation shows fracture of both pins. It is of interest that the ulnar pin was the first to fracture.
Fig. 6: Synostosis occurred in this forearm in which the ulna was pinned and the radius was treated closed.

lated, and the fracture united with the formation of a radio-ulnar synostosis. In the other patient there was an open fracture of the radius with postoperative infection. The pin was removed. The radius angulated with loss of the interspace. The infection subsequently healed, and the fracture united with the formation of a synostosis.

FIG. 6

RESULTS

The results with four-hole plates were poor, and the method was abandoned after seven fractures of both bones and one fracture of a single bone had been so treated, a total of fifteen fractures with six non-unions, an incidence of 40 per cent.

The results with Eggers' plates were amazingly good; and in retrospect, it is difficult to see why their use was abandoned. Eight fractures of both bones, or sixteen fractures, were treated with plates on each bone with one non-union of the radius and one of the ulna. Ten fractures of both bones were treated with a slotted plate on the radius and a Rush pin in the ulna, with no non-union of the radius. Four fractures of both bones were treated with a plate on the radius and closed reduction of the ulna with no non-union of the radius. One fracture of both bones, which was treated with a plate on the ulna and a pin in the radius, united.

In nine solitary fractures of the radius, one non-union developed. Thus in the total of forty fractures treated with Eggers' plates, there were three non-unions, an incidence of 7.5 per cent.

Rush intramedullary pins were used in the great majority of our patients. There were fifty-one fractures of both bones, a total of 102 fractures so treated, with nineteen non-unions—eight of the radius and eleven of the ulna. There were ten fractures of both bones treated with a Rush pin in the ulna and an Eggers' plate on the radius, with one non-union of the ulna. One fracture of both bones, with a Rush pin in the radius and an Eggers' plate on the ulna, united. Twenty solitary fractures of the radius yielded two non-unions. Twenty-four solitary fractures of the ulna, treated with Rush pins, produced four non-unions. This gives a total of 157 fractures treated with Rush pins, yielding twenty-six non-unions, or an incidence of 16.6 per cent.

DISCUSSION

Smith and Sage, in their study of 321 fractures treated by intramedullary fixation of various types, concluded that an over-all non-union rate of 14 per cent was respectable. Our over-all non-union rate of 16.6 per cent is close to this figure. These authors further concluded that, in the treatment of radial fractures, intramedullary fixation was not uniformly successful since they found an incidence of non-union of 26 per cent in fifty fractures of the radius alone treated by this method. The series reported here has not borne this out. In twenty fractures of the radius alone, there were only two non-unions, or an incidence of 10 per cent. In the entire series of 157 fractures treated with Rush pins, the radius yielded a lower rate of non-union (13.9 per cent) than did the ulna (18.8 per cent). Jinkins, Lockhart, and Eggers reported similar experience and concluded that the radius is more suitable for intramedullary pinning than the ulna. They, too, prebent the rod and inserted it just lateral to Lister's tubercle. The ulna, they believe, is not suited for a round intramedullary pin because the canal is straight and there is poor fixation for rotatory stress. Furthermore, they point out that there is much more rotatory stress on the ulna than on the radius, because the ulna cannot rotate at the elbow, whereas the radius has free rotatory motion. The series reported here tends to bear out this contention, with an over-all non-union rate in the ulna of 18.8 per cent. Comparing the results obtained with the Rush pin with those with an Eggers' plate, in this series and with those in Jinkins, Lockhart, and Eggers' report, it appears that Rush pins are less satisfactory. This, however, is not an altogether fair conclusion. In our series Eggers' plates were used in more favorable cases. Only two open fractures were treated by this method. Also when these plates were used the average duration of external immobilization was eighteen weeks. In the Rush pin series, on the other hand, there were thirty-eight open fractures, and the average duration of external immobilization was 6.7 weeks. In the series reported by Jinkins, Lockhart, and Eggers, external immobilization was from twelve to sixteen weeks. Of importance in evaluating these series is the use of autogenous iliac-bone grafts. In only eighteen fractures (11.5 per cent) in the present series were bone grafts used initially, whereas in the series of Jinkins and associates, fifty fractures (30.3 per cent) were grafted initially. In Sage's series, 33 per cent of the fractures of both bones were grafted, and 16.6 per cent of the fractures of the radius alone were grafted. This is an important factor that must be taken into consideration, because non-union after use of autogenous iliac grafts is rare. In the series of Jinkins and associates, there was only one non-union in the grafted fractures, and in our series there were only two. Combining the Jinkins, Lockhart, and Eggers' series of fifty grafted fractures and the eighteen in this

TABLE I

COMPARISON OF RESULTS

	External Immobilization (*Weeks*)	Bone Graft (*Per cent*)	Non-Union (*Per cent*)
Jinkins series [3]			
165 fractures	14	30.3	4.2
Sage nail [4]			
81 fractures	12	33.3 (Both bones) 16.7 (Radius)	11.1 (6 mos.)
Our Rush pins			
157 fractures	6.7	11.5	16.6

series that were grafted initially, and the thirteen which were subsequently grafted at secondary operations, there is a total of eighty-one fractures treated with bone grafts, with only three non-unions. Comparison of our results using the Rush pin with those reported with the Eggers plate and with the Sage nail is of interest (Table I). Use of Eggers' plates with twice as much external immobilization and a three-times-higher incidence of bone grafts, yielded a rate of non-union equivalent to approximately one-fourth our over-all non-union rate with Rush pins. Use of the Sage nail, on the other hand, with twice as much external immobilization and a three-times-higher incidence of bone grafts, yielded an over-all rate of delayed union and non-union that was equivalent to our rate of non-union in the radius and 11/16 of our over-all rate of non-union.

CONCLUSIONS

1. The boldness with which we accepted Rush pin fixation was not justified, and our period of external immobilization was too short—this will need to be extended.

2. A prebent Rush pin inserted in or near Lister's tubercle and adequate immobilization is an acceptable treatment for fractures of the radius.

3. A Rush pin is probably inadequate fixation for fractures of the ulna, because of poor fixation for rotatory stress. A slotted plate, or possibly a triangular or a diamond nail, appears to be preferable for internal fixation of the ulna.

4. The judicious use of primary iliac grafts and early bone-grafting in delayed union will improve the end results.

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Sarcoma in Paget's Disease of Bone in Australia*

BY HUGH C. BARRY, F.R.C.S., F.R.A.C.S., SYDNEY, AUSTRALIA

Paget's disease of bone appears to be more common in Australia than in many other countries. This impression is based mainly on discussions with surgeons from overseas during the last fifteen years. Moreover, I had the opportunity of working in English hospitals for five years before World War II and have made two visits to the United States and one to China during the last few years. The disease is known to be extremely rare in the Chinese [10]. A party of Australian doctors who visited China in 1957 [1] found no report of a case there in recent years and Hodgson, working in Hong Kong, stated that he had not seen a case in the Chinese community in the last nine years. The incidence in America appears to be considerably less than that in Great Britain, but no figures are available to confirm this impression. Many visitors to Australia have noted the apparent frequency of the disease in this country. In New South Wales, where Paget's disease is common after the age of forty, I have noted it only in those who are native born or who have emigrated to Australia from the United Kingdom and are of Anglo-Saxon origin. Moreover, in the records of the last ten years at Royal Prince Alfred Hospital (1,000 beds), all cases of Paget's disease of bone belong to this group with the exception of one immigrant who was born in Germany.

In Australia, the great majority of patients with Paget's disease have neither symptoms nor clinical signs; the diagnosis is made only from routine roentgenographic examinations for unrelated reasons. Pain is very seldom a complaint, and only rarely does pain present a problem in treatment. This absence of pain in Paget's disease in Australia is at a variance with the experience of clinicians in other countries. In Australia, it is usually considered unnecessary and even unwise to report the presence of the disorder to patients, and unfortunately in the hospital records the disease, even when noted, often is not cross-indexed. The patients, who are admitted to a hospital for Paget's disease, are usually suffering from fractures, the majority of which occur in the subtrochanteric region of the femur. I have had the opportunity of treating over forty of these subtrochanteric fractures during the last fifteen years. Many elderly patients, who are admitted with systemic disorders, are found to have Paget's disease; but, except in cardiovascular disease, the bone disorder is not thought to be of any special significance. In the records that are available, the disease is rare under forty years of age, but thereafter its incidence increases steadily. Men are affected nearly twice as often as women. In Sydney some orthopaedic surgeons see one or two new cases of Paget's disease a month, and many general practitioners have seen over 100 cases during the course of their professional life.

In contrast to the high incidence of Paget's disease of bone, the development of sarcoma in Paget's disease is rare in Australia. Some surgeons have seen over 100 cases of Paget's disease of bone and have not yet encountered a single instance of malignant change. Although it is impossible to give any accurate assessment of the incidence of malignant change, it is probably less than 1 per cent. This contrasts sharply with the views of some American writers who have placed the incidence of malignant change as high as 10 per cent [3-7]. In order to study the nature

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, May 31, 1960.

of bone sarcoma arising in Paget's disease in Australia, the records of the four teaching hospitals in Sydney during the ten-year period 1950 through 1959 were reviewed. In this ten-year period there were twenty-nine cases of sarcoma arising in Paget's disease of bone in these four teaching hospitals which serve a population of approximately two million people. This series has recently been reported [2]. Two more patients have come under my personal care since this series was published. It is the purpose of this paper to present these cases (Cases 7 and 8) together with several other cases which show interesting features as regards the pathological findings and length of survival. In addition it is the purpose of this paper to discuss certain other aspects of these bone tumors including the age and sex incidence, the site of the primary growth, the apparent development of multiple malignant lesions, and the relation of trauma to the development of sarcoma.

In the cases treated in Sydney, there were eleven female and twenty male patients, and the average age was sixty-four years. The youngest patient was a man fifty years old. In ten patients, the primary growth developed in the shoulder girdle or humerus; in five, in the upper end of the humerus; in two, in the lower end of the humerus; in two, in the acromion; and in one, in the scapula. There were six tumors arising in the femur, six in the tibia, five in the pelvis, two in the spine, and two in the skull. Other writers have noted the high incidence of sarcoma in the humerus [5,8,11]. This is a site which is usually not affected by Paget's disease until the disorder has become widespread throughout the skeleton. In several cases there were multiple sarcomatous lesions, and it was impossible even at autopsy to determine if some of the lesions were actually secondary to a primary focus or if all were multiple primary malignant lesions. In eight patients tumors developed in the skull, but in all but one of these it appeared that the malignant change had occurred here later than in the other sites in the body. In some cases the swellings on the skull were associated with osteolytic areas as seen on roentgenograms. At other times, it was quite impossible when viewing the roentgenograms to determine where the malignant change had actually started or spread. The tumors on the skull feel soft and may develop quite rapidly, but in this series death occurred before any fungation developed. When present, the skull tumors presented a striking but ominous feature of the disease.

The effect of trauma on the development of a sarcoma has been discussed by others [8]. In five patients in this series there was a definite history of local trauma preceding the malignant change. Three complained of symptoms following a fall on the shoulder (Case 4) and one after a bump on the shin (Case 6). Several other tumors were associated with fractures at the site of the malignant lesion. In two of these, however, which were seen personally shortly after a fracture of the femoral shaft, a large sarcomatous area was already present and the fracture was clearly a recent crack through the remaining portion of the shaft. There was no case with clinical or roentgenographic evidence which indicated that a fracture had occurred prior to the development of the sarcoma. It is also noteworthy that only one sarcoma developed in the subtrochanteric region of the femur, and yet this is the common site for fractures to occur. No malignant change developed after a surgical procedure. Many of the fractures of the femur were treated by internal fixation, either plating or intramedullary nailing. When an intramedullary nail was used special care was always taken to drill the medullary cavity before insertion of the nail since the bone is unusually brittle. In some cases, of course, deformity is so great that internal fixation cannot easily be used. I have also performed several subtrochanteric displacement osteotomies, one compression arthrodesis of the knee, and cortical bone-grafting to the tibia without any complication. In a few patients, however, after a fracture or some surgical interven-

FIG. 1

FIG. 2-A

Fig. 1: A typical healing subtrochanteric fracture of the shaft of the femur showing an area of rarefaction near the fracture site suggesting malignant change in a patient with Paget's disease of bone. This rarefaction has been observed occasionally without subsequent development of sarcoma.

Fig. 2-A: Case 1. Chondrosarcoma in the upper end of the humerus in a woman, seventy years old, with Paget's disease. The tumor appears lobulated and thickening of the cortex of the shaft can be seen. (Reprinted by permission from Sarcoma in Paget's Disease of Bone by H. C. Barry, Australian and New Zealand J. Surg., **29**: 304–310, 1960.)

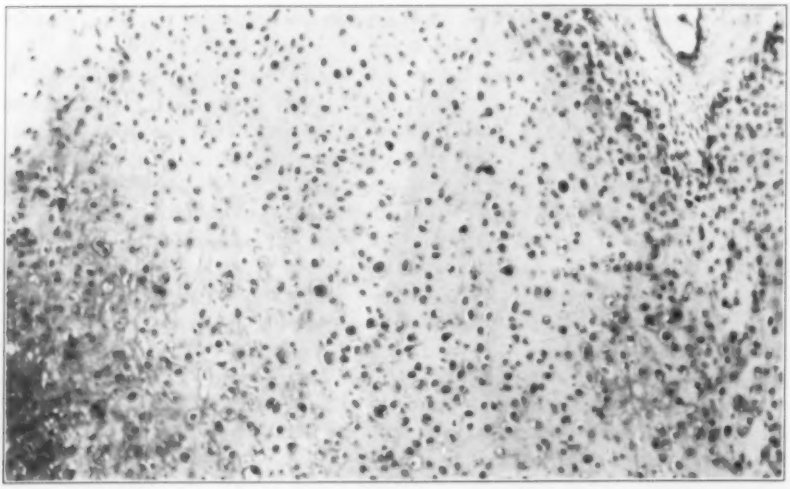

FIG. 2-B

Section of chondrosarcoma. Other areas were more cellular with typical malignant changes.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 2. Roentgenogram of the lower third of the femur in a woman, sixty-six years old, with widespread Paget's disease. A circumscribed soft-tissue tumor associated with a recent pathological fracture can be seen. The roentgenographic appearance suggested sarcoma. (Reprinted by permission from Sarcoma in Paget's Disease of Bone by H. C. Barry, Australian and New Zealand J. Surg., **29**: 304–310, 1960.)

Fig. 3-B: Roentgenogram made two years later. The soft-tissue swelling had disappeared. This patient lived nearly eight years after sustaining the pathological fracture. (Reprinted by permission from Sarcoma in Paget's Disease of Bone by H. C. Barry, Australian and New Zealand J. Surg., **29**: 304–310, 1960.)

tion, localized rarefaction of bone suggesting a premalignant phase was observed (Fig. 1). The cause of this is obscure but in no patient has sarcoma developed.

Although the prognosis for survival with these sarcomata has been almost universally bad, it is well known that their microscopic appearance varies widely. In seventeen cases in this series histological material was studied; there was one fibrosarcoma, one chondrosarcoma (Case 1), and fifteen osteogenic sarcomata. No case of giant-cell tumor has been found in Sydney, but I am indebted to Mr. Bryan Keon-Cohen of Melbourne for an interesting example of this lesion which is to be reported (Case 5). Others have described this tumor arising in Paget's disease of bone [5,9].

Amputation was performed in six cases but none of the patients survived for more than twelve months after operation. Eighteen patients were treated with deep roentgen therapy. Several appeared to have had palliation of their symptoms and one with large tumors in the skull showed definite regression of the swellings. One patient with a tumor in the upper end of the left humerus, demonstrated by biopsy to be a sclerosing osteogenic sarcoma, declined forequarter amputation and was given deep roentgen therapy; he lived for three years and eight months (Case 3). Another patient, a woman, sixty-six years old, with a soft-tissue swelling associated with a pathological fracture at the lower end of the femur, was treated with deep roentgen therapy. The swelling disappeared, the fracture healed by fibrous union, and the patient survived for eight years. Unfortunately no biopsy was done, and the nature of the mass is not known (Case 2). Apart from these two cases, the longest survival in the Sydney series was fifteen months after the diagnosis was made.

FIG. 4

Case 3. Roentgenogram of the left shoulder of a man, fifty-six years old, showing sarcoma of the upper end of the humerus with Paget's disease of bone. This patient survived for three years and eight months. (Reprinted by permission from Sarcoma in Paget's Disease of Bone by H. C. Barry, Australian and New Zealand J. Surg., **29**: 304–310, 1960.)

CASE 1. K. N., a woman seventy years old, was first seen in 1953 with a history of pain and swelling in the right shoulder of four months' duration. Roentgenographic examination showed Paget's disease of the humerus, but no other parts of the skeleton were affected. Biopsy of the proximal end of the humerus revealed chondrosarcoma and a forequarter amputation was performed. The specimen showed a well circumscribed lobulated mass arising from the humeral shaft which was thickened by Paget's disease (Fig. 2-A). The microscopic sections confirmed the growth as chondrosarcoma (Fig. 2-B). The patient died nine months after amputation with metastases in the lung.

CASE 2. M. O., a woman sixty-six years old, was admitted to the hospital on November 10, 1947, with a fracture of the middle one-third of the shaft of the left femur. Open reduction and fixation with a plate were performed. Roentgenograms made at this time showed advanced Paget's disease in both femora. On April 21, 1949, she sustained a pathological fracture of the lower end of the right femur, and roentgenograms showed not only marked erosion of the bone at this level but also a large round soft-tissue tumor in the popliteal space measuring three by four inches (Fig. 3-A). This was considered to be malignant, but biopsy was not done. She was given deep roentgen therapy (3,000 r) over a period of three weeks, and the condition improved steadily. The fracture never quite consolidated, but the area of bone destruction became sclerosed and the soft-tissue tumor disappeared entirely (Fig. 3-B). She lived for nearly eight years after sustaining the pathological fracture. Unfortunately the nature of the tumor in this case was never ascertained. On palpation the mass appeared to be solid and was not tender. It did not suggest a hematoma, and it was clearly visible in roentgenograms made at the time. Its behavior, however, indicated that it was probably not a sarcoma.

CASE 3. C. McG., a man fifty-six years old, was admitted to the hospital on February 24, 1948. He had had pain in his left shoulder for the previous eighteen months. A roentgenogram showed what appeared to be sarcoma of the upper end of the humerus (Fig. 4) and a biopsy speci-

FIG. 5-A

Case 4. A man, fifty years old, with sarcoma of the upper end of the left humerus and sarcomatous deposits in the skull. (Reprinted by permission from Sarcoma in Paget's Disease of Bone by H. C. Barry, Australian and New Zealand J. Surg., **29:** 304–310, 1960.)

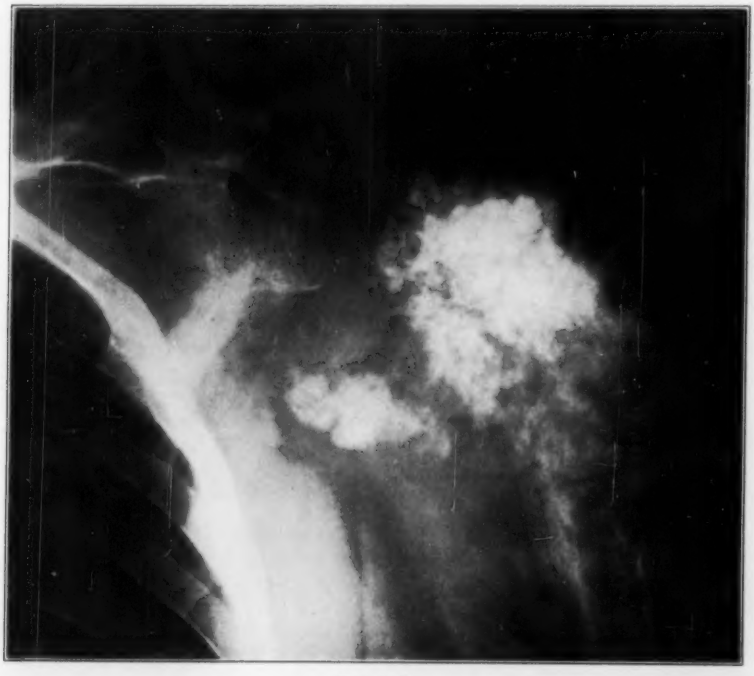

FIG. 5-B

Roentgenogram showing sarcoma of the upper end of the humerus. Patient had extensive Paget's disease. (Reprinted by permission from Sarcoma in Paget's Disease of Bone by H. C. Barry, Australian and New Zealand J. Surg., **29:** 304–310, 1960.)

men showed sclerosing osteogenic sarcoma and Paget's disease of bone. The patient was advised to have a forequarter amputation but refused; he was given deep roentgen therapy. Large metastases developed in his chest which were visible by roentgenogram, but no changes occurred in the skull. The tumor of the shoulder slowly increased in size but the patient remained remarkably comfortable, and he was last seen three years and eight months after the diagnosis was made. He was then lost to follow-up.

Case 4. R. C., a man fifty years old, was admitted to the hospital on July 4, 1956, with a history of a fall on his shoulder. There was a swelling of the shoulder; later, lumps in his skull and sternum developed. Roentgenograms showed extensive Paget's disease in the skeleton and sarcoma of the upper end of the humerus. There were also osteolytic lesions in the skull corresponding with the site of the tumors there. He was treated by deep roentgen therapy with no benefit and died four months later (Figs. 5-A, 5-B, and 5-C).

Fig. 5-C

Roentgenogram of the skull showing osteolytic lesions which were associated with soft-tissue tumors. (Reprinted by permission from Sarcoma in Paget's Disease of Bone by H. C. Barry, Australian and New Zealand J. Surg., **29**: 304–310, 1960.)

Case 5 (Mr. Keon-Cohen's case). P. B. was first seen in 1932 when he was fifty years old. Roentgenograms made at this time showed typical changes of osteitis deformans involving the right tibia and extending up to the knee joint. In March 1957, when he was seventy-five years old, a lump developed in the middle third of his right shin. This grew rapidly and started to fungate shortly before amputation was performed on July 11, 1957. Although the clinical picture suggested a rapidly growing sarcoma, the histological appearance was that of a low-grade giant-cell tumor. Sections were taken from different aspects of the growth, but all showed this type of lesion. After amputation, there were no signs of metastases. The patient died three years later from a coronary occlusion. This is the only case of giant-cell tumor arising in Paget's disease of bone that I know of in Australia (Figs. 6-A, 6-B, and 6-C).

FIG. 6-A

FIG. 6-B

Fig. 6-A: Case 5. Roentgenogram of the tibia in a man, seventy-five years old, with widespread Paget's disease and giant-cell tumor arising from the anterior aspect of the tibia.

Fig. 6-B: Amputation specimen showing giant-cell tumor arising from the anterior aspect of the tibia.

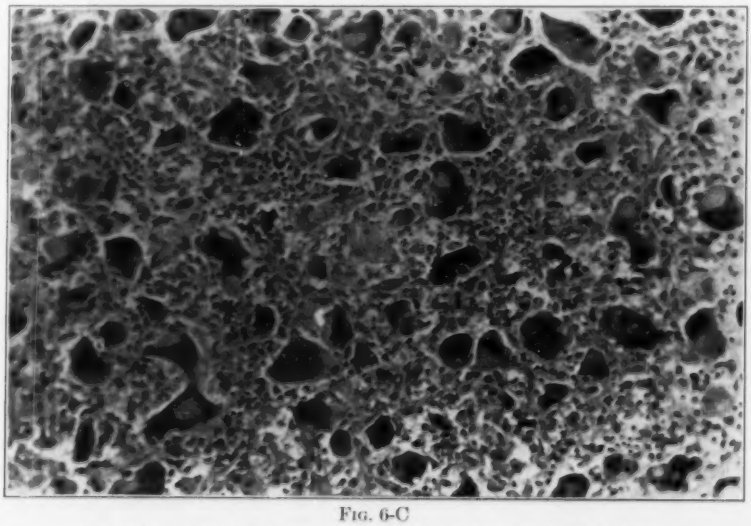

FIG. 6-C

Section from giant-cell tumor of the tibia showing characteristic features.

CASE 6. H. G., a man sixty-three years old, bumped his shin, and a swelling, seven by five by 1.5 centimeters, developed at the site of injury. Six weeks later his tibia snapped when walking and a roentgenogram showed a comminuted fracture of the upper third of the tibia with well marked changes of Paget's disease present. This fracture was soon followed by gross destructive changes indicating sarcomatous degeneration (Fig. 7). The patient was given deep roentgen therapy without any sign of improvement. Five months after the original injury, the extremity was amputated through the middle third of the thigh. One month later he fell and sustained a subtrochanteric

FIG. 7

Case 6. Sarcoma of the upper end of the tibia in a man, sixty-three years old, with widespread Paget's disease of bone. The sarcoma followed a bump on his shin.

fracture on the same side. Soon after this he showed roentgenographic evidence of a second sarcoma arising in the pelvis. A needle biopsy of this tumor showed necrotic cells with the general outline of osteogenic sarcoma. He died about fifteen months after the original accident. No autopsy was performed.

This case suggests that localized trauma may sometimes precipitate a malignant change in this type of bone. The sarcoma in the pelvis may have been a second primary malignant lesion. Sarcoma did not develop at the site of the subtrochanteric fracture.

FIG. 8-A

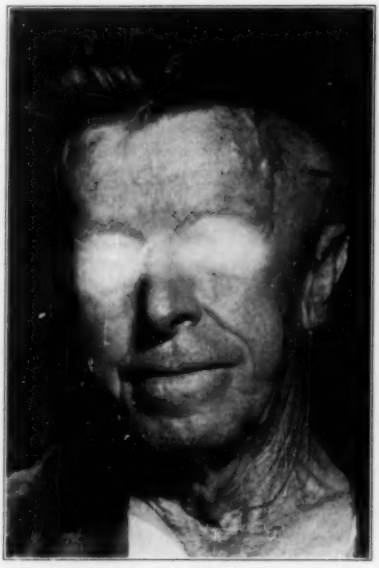

FIG. 8-B

Fig. 8-A: Case 7. A man, seventy-one years old, with marked bowing of the lower extremities resulting from widespread Paget's disease of bone. Several transverse fractures in the right femur and tibia occurred, as well as sarcoma of the skull.

Fig. 8-B: Soft-tissue mass in the parietal region.

FIG. 9

Case 8. Roentgenogram of the left elbow of a man, fifty-five years old, showing sarcoma of the lateral condyle of the humerus. This patient had a brother who also had Paget's disease with the development of sarcoma.

CASE 7. T. N., a man seventy-one years old, was admitted to the hospital on May 15, 1959, with fractures in the subtrochanteric region of the right femur and in the shaft of the right tibia. Both fractures were transverse and undisplaced. He had such marked bowing of both lower limbs that he had had to walk with his legs crossing each other. The patient was kept in bed for four months with his right leg in a plaster cast but with no fixed immobilization of the femur. The undisplaced fractures united; but, when he started to walk again (with two canes), he sustained two more fractures of the tibia. He was then confined to a wheel chair, without any external splinting, until shortly before his death. On September 25, 1959, he was readmitted with a soft swelling about four centimeters in diameter in the left temporal region of his skull. This was treated by Co^{60} and appeared to regress. Another swelling soon developed in the skull nearby and was similarly treated. He died on March 24, 1960, and at autopsy, although there was advanced Paget's disease throughout the skeleton, the only malignant change (osteogenic sarcoma) was noted in the skull. The neoplasm had invaded the brain, and small deposits were scattered through both lungs (Figs. 8-A and 8-B).

CASE 8. F. M., a man fifty-five years old, first felt slight pain in the left elbow on September 1, 1960. He had been felling timber for several months previously, as well as handling sheep and performing all the duties associated with life on the land. He continued at these duties, but a roentgenogram made on December 13, 1960, showed an area of cortical erosion in the lateral condyle of the left humerus and well marked Paget's disease of the bone (Fig. 9). A biopsy carried out on December 23, 1960, revealed osteogenic sarcoma. In view of the extremely poor prognosis, amputation was not advised and he was treated by Co^{60}. A tumor dose of 6,000 r was given over a period of thirty-five days. He was kept under observation and was last seen in October 1961.

This man has an extraordinary family history. He was born and has lived all his life in a country town of New South Wales. A younger brother died at the age of fifty-three, four years before the time of writing, with a sarcoma of the sacrum arising in Paget's disease. His presenting symptom was sciatica but his health rapidly deteriorated and chordotomy was performed to give partial relief of pain before his death six months later. Two other brothers and one sister are alive and well. A paternal aunt had Paget's disease with bow legs and died of heart failure; and a paternal uncle, now living in New Zealand, is reported to have Paget's disease.

It is not uncommon to note the occurrence of Paget's disease in more than one member of a family but this is the only case I know of in which two members of the same family have had sarcoma.

SUMMARY

Paget's disease of bone appears to be unusually common in Australia. It has been noted, however, only in those of Anglo-Saxon origin who have either been born in Australia or who have emigrated there from the United Kingdom. It is known to be extremely rare and possibly unknown in the Chinese.

In Australia, the disease is usually symptomless and pain is a rare feature—pathological fractures occur quite commonly, most often in the subtrochanteric region of the femur.

The incidence of malignant change is considered to be very low in Australia and is probably less than 1 per cent. A series of twenty-nine bone tumors arising in Paget's disease (twelve not proved by biopsy), that were treated in the teaching hospitals of Sydney during 1950 through 1959, has been reviewed. In addition two more recent personal cases are reported, making a total of thirty-one.

One-third of these neoplasms developed in the upper arm or shoulder girdle and nearly one patient in four had a tumor in the skull. Several patients had multiple malignant lesions.

In five cases there was a history of trauma prior to the development of a sarcoma, but there was no evidence that a malignant change developed as the result of a fracture or surgical intervention.

All of these tumors were osteogenic sarcomata except for one fibrosarcoma, one chondrosarcoma, and one giant-cell tumor which have been reported in detail together with a soft-tissue tumor of unknown pathology with which the patient survived eight years after roentgen therapy.

A family is reported in which two brothers had sarcomata in Paget's disease.

Treatment consisted in amputation, deep roentgen therapy, and palliative measures; the results are noted.

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DISCUSSION

Dr. J. Vernon Luck, Los Angeles, California: Bone sarcoma is truly the most catastrophic complication of Paget's disease. Whereas it may occur in rare instances in a patient with monostotic involvement, it generally appears in those with widespread or polyostotic distribution. Medical literature in this country is conflicting in reports of the incidence of sarcoma developing in bone at sites of involvement by Paget's disease. An estimate that this complication occurs in 10 to 15 per cent of patients with Paget's disease can be found in several reports. In other reports the incidence is as low as 0.9 per cent, as in the report of 1,753 patients studied at the Mayo Clinic by Porretta, Dahlin, and Janes. This is indeed a wide difference of incidence. Careful study of the reports from this country reveals the cause of this disparity. In the reports which estimate the incidence of bone sarcoma to be 10 to 15 per cent, the author is reporting widespread symptomatic polyostotic Paget's disease. By sharp contrast, papers which report an incidence of approximately 1 per cent are reporting a very large number of cases in which Paget's disease was diagnosed only by roentgenographic examinations carried out for symptoms and disability from causes other than Paget's disease. In other words, the Paget's disease was an incidental finding by the radiologist. Schmorl has shown us that approximately 3 per cent of persons over the age of forty coming to autopsy will have some degree of Paget's disease—most commonly in the vertebral column and pelvis.

Mr. Barry has emphasized that the cases of his report include those diagnosed by the radiologist as an incidental finding. Therefore, if the incidence in Australia is approximately that of this country, the incidence would be expected to be approximately 1 per cent, and this is what the author has observed. The incidence appears to be approximately the same in the two countries when comparable series of cases are analyzed.

It was recently my opportunity to treat a patient from the author's city, Sydney, Australia, for an osteogenic sarcoma of the tibia developing as a complication of widespread Paget's disease. This gentleman, seventy-four years old, was making a trip around the world and increasingly severe pain in his right leg developed during this trip. When he arrived in Los Angeles, the pain had become intractable, and roentgenograms showed infraction of the posterior wall of the tibia as a result of the osteolytic action of the tumor. A biopsy was carried out, indicating that in the sections studied the lesion was an anaplastic fibrosarcoma. Therefore, an amputation above the knee was performed. After uneventful healing, a prothesis was fitted, and the patient returned to Sydney. No doubt in many cases of bone sarcoma in Paget's disease, the excruciating pain is due to infractions of the cortical walls of the affected bone which may appear long before a frank pathological fracture. Although the treatment in this case was considered to be only palliative, it was in good order to carry out the amputation.

I have never personally known of a patient who had definite bone sarcoma associated with Paget's disease who survived beyond one or two years.

The biopsy is decidedly important. It is not possible in many instances to make a certain diagnosis of bone sarcoma complicating Paget's disease from a study of the roentgenograms alone. There can be osteolytic foci of Paget's disease which are painful and which are not the result of bone sarcoma. It would therefore appear to be a proper part of the procedure, prior to ablative surgery, to clearly establish the diagnosis by biopsy.

The type of sarcoma that develops varies rather widely in Paget's disease. In some cases the fibrosarcoma component dominates; in others the osteosarcoma; and in some the chondrogenic element is more evident. In bone sarcomata, not associated with Paget's disease, one tissue dominates far above the others. In Paget's disease, there is frequently a substantial component of all of the elements—in other words, fibrosarcoma, osteosarcoma, and chondrosarcoma. In chondrosarcomata, not associated with Paget's disease, the prognosis is considerably better than with osteosarcoma. In association with Paget's disease, it appears to be equally catastrophic. It is not rare to see large numbers of giant cells in sarcoma in Paget's disease, and in fact, in several instances in the literature, malignant giant-cell tumors have been reported in association with Paget's disease. In all probability if these cases were studied in their entirety—that is, if the entire specimen were studied microscopically—it would be found that other components were prominent. Benign giant-cell tumors have been observed, however, and have not always been associated with malignant transformation.

It is interesting to note that in the series of Mr. Barry's report, there was a high incidence of involvement of the shoulder girdle. In contrast, the incidence in Southern California appears highest in the tibia and femur. We agree that trauma has not appeared to play any part in the development of malignant transformation. Multicentric sarcomata developing in areas of bone involvement by Paget's disease have been noted many times.

Intertrochanteric Osteotomy in Fixed Paralytic Obliquity of the Pelvis

A PRELIMINARY REPORT

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Fixed pelvic obliquity, a term coined by Mayer in 1931, refers to a composite deformity caused by poliomyelitis. The elements of this deformity are sometimes difficult to discern; the most significant are contractures around the hips. Mayer and, later, Irwin established the importance of these contractures in initiating the deformity of fixed pelvic obliquity. According to them, treatment should be aimed first at the hip deformity by division of the contracted soft tissues and stabilizing procedures [2] or by subtrochanteric osteotomy [1]. As far as we have been able to ascertain, there have been no references to the subject of fixed pelvic obliquity in the literature since the work of Mayer and Irwin, although the problems associated with the paralytic hip have been dealt with quite often.

The purpose of this paper is to present evidence that intertrochanteric osteotomy, by achieving complete correction of the hip deformity, can correct fixed pelvic obliquity and lessen the disability resulting from this deformity. However, in view of the relatively short follow-up, the results reported here must be considered preliminary.

DEFINITION

As defined by Irwin, true fixed pelvic obliquity is present when the pelvis is held in a fixed oblique position by contractures both above and below the pelvis.

Having followed a certain number of our patients from the onset of paralysis, we feel that in fixed pelvic obliquity a distinction should be drawn between the contractures occurring below and those occurring above the pelvis since they differ in their degree of fixity and relative importance with regard to disability.

Fixed pelvic obliquity is a composite deformity consisting of contractures of both hips—one in abduction and the other in adduction—and scoliosis. Ultimately, all these elements become fixed or uncorrectable, and then it is not possible to make any distinction between the primary and the secondary factors involved in the production of the deformity. However, when the patients are followed from the onset of poliomyelitis it is quite easy to see that most fixed pelvic obliquities are initiated by a contracture of one hip. At the beginning, contracture of this hip will be the only fixed element of the composite deformity. The opposite hip and the spine will assume compensatory attitudes but the latter will for some time remain correctable. In the course of time and with continued growth these compensatory attitudes gradually become fixed because of adaptive changes.

In our experience, in patients with unilateral paralysis and no trunk involvement, the involved hip has remained the only fixed element of the deformity for a very long time. In patients with bilateral paralysis and no trunk involvement, in the contralateral hip, which did not have a deformity at the beginning, a contracture developed quite rapidly and became fixed, whereas the spine remained correctable, at least partly so, for a long time. The same sequence of events occurred in

patients in whom both lower extremities and the trunk were affected, but the spine became fixed more rapidly, although always less rapidly than the contralateral hip. Thus, in all patients in this series the spine was more or less correctable; in no instance was it completely fixed.

The disability in the fixed pelvic obliquity results from disruption of all the normal weight-bearing lines and lever systems concerned in locomotion. (These factors were amply described by Mayer and by Irwin and it would be superfluous to discuss them here.) In locomotion the lower extremities represent the most important factor, the spine playing but a secondary role. Scoliosis, whatever its cause, does not create locomotor disability, at least directly. Thus, even totally fixed scoliotic contractures occurring above the iliac crests do not have a direct bearing on the major disability of fixed pelvic obliquity, even though the scoliosis has been caused by the pelvic obliquity.

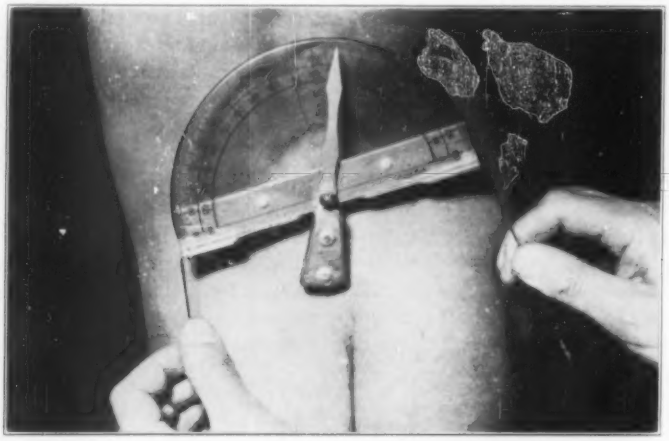

FIG. 1

Measurement of the pelvic tilt in relation to the line of gravity. When the patient is standing, the line of gravity coincides with the mid-line of the body. The base of the protractor is superimposed on the line joining both posterior iliac spines. The weighted needle indicates the line of gravity, and thus the angle of pelvic tilt can be read directly.

In this report the term *fixed pelvic obliquity* is used in a somewhat restricted sense. Problems related to the spine are excluded; only the direct result of a contracture or contractures of the structures connecting the pelvis and thighs are considered. The presenting sign of this deformity is demonstrated when both lower extremities are brought together and the pelvis is observed to rotate out of its normal alignment at right angles to the mid-line of the body. With the limbs in this position, the pelvis is fixed and cannot be squared even when the patient is in the recumbent position as long as both limbs remain alongside each other in the position they assume during standing or walking.

The degree of pelvic obliquity can be measured roughly as the angle made by a line joining both posterior iliac spines with the mid-line of the body. Since the latter coincides with the line of gravity when the patient is standing, an easy check can be obtained with a weighted goniometer (Fig. 1). In this way the scoliosis can be disregarded, the line of gravity providing the reference point against which the pelvic tilt is estimated. When we speak of correction of the fixed pelvic obliquity, we mean realignment so that the line joining the posterior superior spine remains perpendicular to the line of gravity when the patient is standing and to the mid-

line of the body when both lower extremities are brought alongside each other in the recumbent position. This realignment of the pelvis was achieved in our patients by realignment of one or both lower extremities, with regard to the mid-line of the body, by correction of the hip contractures alone. It may be presumed that in our patients the contractures above the iliac crests were correctable, at least sufficiently to allow the return of the pelvis to its normal position once the effect of the contractures below the pelvis had been abolished. Although the scoliosis remained unchanged in these patients this did not influence the therapeutic effect; the scoliosis, therefore, has been disregarded in this study, as explained previously.

Practically all the patients in this series had a flexion deformity of the hip associated with the abduction or adduction contracture. Obviously, a flexion deformity does not contribute to the pelvic obliquity but does throw the pelvis out of alignment in the sagittal plane, thus adding considerably to the complexity of the deformity and contributing to the over-all disability. If the deformities in the coronal plane (abduction or adduction contractures) account for the difficulty in walking through disturbance of the levers of locomotion [1], the deformity in the sagittal plane (flexion contracture) accounts mainly for the difficulty in maintaining the upright posture since a weak limb with a flexion contracture is unable to support the weight of the body on standing. In practice, these deformities are very much intertwined and aggravate each other.

CLINICAL MATERIAL

Up to the time of writing sixty-three osteotomies were performed on fifty patients (thirteen bilateral osteotomies). Many of these cases, however, have been excluded from this report, either because the follow-up was insufficient or because the patients were very young; the latter will be reported in a later paper, when the effect of growth is known. The cases reported here concern children who were at least eleven years of age at the time of writing and who had been followed for more than one year. The cases reported concern thirteen patients, six of whom had bilateral osteotomies, making a total of nineteen osteotomies.

The case reports are summarized in Table I. For the sake of clarity the cases have been subdivided into the following three groups:

A. Four patients with involvement of one lower limb in whom the affected hip alone was operated on;

B. Three patients with involvement of both limbs in whom one hip was operated on;

C. Six patients with involvement of both lower limbs with operations on both hips.

All these patients had fixed pelvic obliquity caused by contractures of the hip, as already defined. In the majority of patients the pelvic tilt was 10 degrees; although in five, it was 15 degrees. Most of the hip contractures were in abduction ranging from 45 to 10 degrees. All the hips with adduction contractures (10 to 30 degrees) had varying degrees of subluxation.

In addition to the pelvic tilt in the coronal plane, there was a deviation in the sagittal plane (flexion contracture) in all the hips. These flexion contractures ranged from 20 to 90 degrees. Although quite apparent in a great number of cases, the coronal deformity of the hip was often masked by the flexion contracture, particularly when the latter was very marked. The presence of an abduction or adduction deformity could always be demonstrated by clinical measurement, by careful testing of the range of motion of the hips, and by roentgenographic examination of the pelvis. Comparative measurements of both lower limbs from the anterior superior iliac spine and from the umbilicus to the medial malleolus showed

TABLE I *

Case No. and Age	Side Involved	Muscle Power†														Pelvic Tilt before Operation (*Degrees*)	Hip Deformity (*Degrees*)			Knee Deformity (*Degrees*)	Age at Operation (*Years*)	Date of Operation
		Trunk				Hip								Knee								
		Flexor	Extensor	Obliqus	Quadratus	Flexor	Extensor	Abductor	Adductor	Ext. Rotators	Int. Rotators	Sartorius	Tensor Fasciae Latae	Flexor	Extensor		Flexion	Abduction	Adduction			
1, 17 yrs.	Rt.	5	5	5	5	3	0	2+	0	0	0	2+	C	0	0	10 to the right	60	30		Flexion, 30	15	2/58
2, 11 yrs.	Rt.	5	5	5	5	2+	0	3	0	0	0	2	2	0	0	10 to the right	30	10		Flexion, 20	9	3/58
3, 11½ yrs.	Rt.	5	5	5	5	4	2+	4	2	3	2	3	4	3	2	10 to the right	30	20		Flexion, 20	9¼	7/59
4, 11 yrs.	Rt.	5	5	5	5	3+	2+	4	1	4	0	4	4	3	3	10 to the right	30	20		Flexion, 20	9	8/59
5, 22 yrs.	Rt.	5	5	5	5	3	1	3	0	2	0	3	3	3	3	10 to the right	30	10		None	20	2/58, right
	Lt.	5	5	5	5	3	0	0	2+	0	0	3	3	3	2		10		10, not fixed	None		
6, 14 yrs.	Rt.	5	5	5	5	0	0	0	0	0	0	0	0	C	0	10 to the right	30	20		Flexion, 10	12	3/58, right
	Lt.	5	5	5	5	0	0	0	0	0	0	0	0	0	0		20		10, not fixed	None		
7, 11 yrs.	Rt.	5	5	5	5	4	3	3	0	2+	0	3	3	3	2	10 to the right	30	20		Flexion, 10	9	6/58, right
	Lt.	5	5	5	5	3	0	0	2	0	2	2	3	0	0		20		10, not fixed	None		
8, 12 yrs.	Rt.	4	4	4	4	3	2	3	0	3	2	4	C	3	2	15 to the right	90	20		Flexion, 30	10	6/58
	Lt.	4	4	2	2	4	0	0	4	2	3	4	C	2	2		90		30	Flexion, 30	10	6/58
9, 14 yrs.	Rt.	5	5	5	5	3	3	3	0	3	2	3	3	3	2	10 to the right	30	10		Flexion, 10	12	9/58
	Lt.	5	5	5	5	0	2+	0	2	0	2	3	3	2	0		30		10	Recurvatum, 20		
10, 11 yrs.	Rt.	4	4	2	3	2	0	0	3	1	2	0	0	0	0	15 to the left	45		20	Flexion, 20	9	2/59
	Lt.	4	4	1	2	2	0	3	0	2+	1	2	2	3	0		45	10		Flexion, 20		2/59
11, 13 yrs.	Rt.	3+	3	3	4	2+	3	3	0	4	0	4	3	3	2	15 to the right	30	20		Flexion, 20	12	6/59
	Lt.	3+	4	3	4	3+	2	0	3	2+	4	4	3	4	2		30		10	Flexion, 20		6/59
12, 12 yrs.	Rt.	3	5	3	5	2	3	0	3+	1	1	3	C	2	0	15 to the left	60		15	Flexion, 30	11	8/59
	Lt.	5	5	4	5	1	3	4	0	0	1	3	C	1	0		60	45		Flexion, 30		8/59
13, 14 yrs.	Rt.	5	5	5	5	4	2	3	2	3	2+	3	C	3	2	15 to the right	60	10		Flexion, 30	13	9/59
	Lt.	5	5	5	5	3	2	0	4	2	3+	3	C	3	0		60		10	Flexion, 30		9/59

* Cases 1 through 4 are from Group A (involvement of one lower extremity); Cases 5 through 7 are from Group B (involvement of both lower extremities and unilateral osteotomy); Cases 8 through 13 are from Group C (involvement of both lower extremities and bilateral osteotomy).

† Grading of muscle power: 5=normal; 4 = good; 3 = fair; 2 = poor; 1 = trace; 0 = none; and C = contracted.

‡ The functional results are graded as follows: *Walking:* 0 = impossible even with support; 1 = possible with sup-

TABLE I *

Concomitant Ancillary Procedures	Functional Results as Compared to Preoperative Disability‡									Pelvic Tilt after Operation (*Degrees*)	Amount of Shortening Caused by the Operation (*Centimeters*)	Postoperative Condition			Remarks
	Walking		Use of Apparatus		Activity		Total Disability		Grade of Improvement			Knee Stability	Motion in Hip	Motion in Knee	
	Pre-op.	Post-op.	Pre-op.	Post-op.	Pre-op.	Post-op.	Pre-op.	Post-op.							
Soft-tissue release, same incision; supracondylar osteotomy	1	3	2	3	2	4	5	10	5	0	0	Good	Free	Free	
Supracondylar osteotomy	2	3	2	3	2	4	6	10	4	0	2	Good	Free	Free	
Supracondylar osteotomy	3	4	4	4	2	4	9	12	3	0	1	Good	Free	Free	
Supracondylar osteotomy	3	4	2	4	2	4	7	12	5	0	1	Good	Free	Free	Previous fasciotomy
None	3	4	3	3	2	3	8	10	2	0	0	Good	Free	Free	
	3	4	3	3	2	3	8	10	2	0	0	Good	Free	Free	
Supracondylar osteotomy	1	1	1	1	2	2	4	4	0	0	0	Good	Free	Free	
	1	1	1	1	2	2	4	4	0	0	0	Good	Free	Free	
Supracondylar osteotomy	1	3	1	3	2	4	4	10	6	0	0	Good	Free	Free	Previous fasciotomy on right
	1	3	1	3	2	4	4	10	6	0	0	Good	Free	Free	
Muscle stripping, separate incision; supracondylar osteotomy	0	2	0	1	0	4	0	7	7	0	0	Good	Free	Free	Previous fasciotomy on right
Muscle stripping, separate incision; supracondylar osteotomy	0	2	0	1	0	4	0	7	7	0	0	Good	Free	Free	
Supracondylar osteotomy	1	3	1	2	2	3	4	8	4	0	0	Good	Free	Free	
None	1	3	1	2	2	3	4	8	4	0	0	Recurvatum, 20°	Free	Free	
Supracondylar osteotomy	1	2	1	1	1	4	3	7	4	5	0	Good	Free	Free	Previous fasciotomy on left
Supracondylar osteotomy	1	2	1	1	1	4	3	7	4	5	0	Good	Free	Free	
Supracondylar osteotomy	1	2	1	2	1	3	3	7	4	0	0	Good	Free	Free	
Supracondylar osteotomy	1	2	1	2	1	3	3	7	4	0	0	Good	Free	Free	
Soft-tissue release, same incision; supracondylar osteotomy	1	2	1	2	1	4	3	8	5	0	0	Good	Free	Free	Previous fasciotomy on left
Supracondylar osteotomy	1	2	1	2	1	4	3	8	5	0	0	Good	Free	Free	
Supracondylar osteotomy	1	2	1	2	1	4	3	8	5	0	0	Good	Free	Free	
Supracondylar osteotomy	1	2	1	2	1	4	3	8	5	0	0	Good	Free	Free	

port but limited; 2 = possible with support; 3 = possible without support but limited; and 4 = free. *Use of Apparatus:* 0 = wheel chair; 1 = two braces and two crutches; 2 = one brace or crutch, or both; 3 = one brace or cane; and 4 = no apparatus used. *Activity:* 0 = wheel chair; 1 = much restricted; 2 = restricted; 3 = partly restricted; and 4 = unrestricted. *Grade of Improvement:* 0 = no improvement; 2 and 3 = improved; 4 and 5 = much improved; and 6 and 7 = very much improved.

the discrepancy between the real and the apparent lengths, thus confirming the existence of pelvic tilt. The limitation of adduction (in abduction contracture) or of abduction (in adduction contracture) was tested as follows: The patient's pelvis was brought as close as possible to the end of the examining table to allow the lower extremities to hang freely over the edge; the contralateral hip was then fully flexed and held in this position, thus fixing the pelvis. The hip being tested and the ipsilateral knee were then extended as far as possible and, only then, was the range of abduction and adduction of the hip measured. Anteroposterior roentgenograms of the pelvis, of course, showed the pelvic tilt and hip subluxation when these were present.

The essential disability of these patients was difficulty in standing or walking, far more severe than could be accounted for by the paralytic involvement alone. This disability is caused by the peculiar pathomechanics of the fixed pelvic obliquity [1,3].

In one-sided involvement, the manifestations were easy tiring, frequent falls, and peculiar habits acquired to overcome the instability of the affected extremity while standing or during the stance phase of gait, such as pressing on the affected thigh with the hand or leaning the thigh against a walking stick. In a number of patients the difficulty increased with growth. Thus, a child whose paralytic involvement allowed him to manage fairly well with a leg brace or even without any brace would show progressive worsening during a one or two-year period coinciding with a spurt of rapid growth. The result was that the brace had to be lengthened, the knee had to be locked, a pelvic ring became necessary, and, finally, crutches were required since even a few steps could not be managed without support.

An almost identical sequence of events was observed in patients with bilateral involvement. A child who managed fairly well with two long leg braces and walking sticks, or even with one brace and one stick, became more and more unstable when standing and walking. A pelvic ring, then a corset articulating with the braces had to be added, and finally crutches or even a wheel chair became necessary. Under the best of circumstances, if the abducted limb was strong enough, a tripod gait was adopted, the child using two crutches and the abducted limb to the total exclusion of the contralateral one, which was left dangling and was used only for slight help in standing.

As the disability progressed, secondary deformities appeared—lumbar scoliosis with convexity toward the abducted side, subluxation of the adducted hip, exaggerated lordosis of the lumbar spine compensating for flexion contracture of the hip, and flexion contracture of both knees. At first correctable, these deformities soon became fixed.

Most of these children had acute poliomyelitis at a very young age and were followed by us for a number of years. Few of them could be considered neglected; the majority had what was considered adequate physiotherapy from the onset, and stretching of contracted tissues around the hips was part of their daily routine for years. In about one-third of these patients fasciotomy and soft-tissue release had been carried out at a relatively early stage (usually two to three years after onset).

No explanation for the failure of conservative treatment in these cases can be given. We suspect that the essential element of fixed pelvic obliquity as previously defined (the hip contractures) is quite resistant to conservative treatment. Soft-tissue release may be adequate for a time, but rapid growth in the presence of muscle imbalance will, almost inevitably, bring about the reappearance of contractures.

RATIONALE OF THE OSTEOTOMY

The rationale of intertrochanteric osteotomy is that it provides one procedure to deal with the main therapeutic problem, the realignment of the lower extremities in relation to the body. This realignment has to be achieved simultaneously in both the coronal plane (pelvic obliquity) and the sagittal plane (flexion deformity). Osteotomy provides the most effective method to gain simultaneous realignment in all planes. For soft-tissue division to achieve this end, the procedure would have to be rather extensive, thus endangering the stability of the hip.

An osteotomy is the only way to deal with the intrinsic bone deformities of the paralytic hip (valgus and anteversion of the neck) and with subluxation. These can be corrected simultaneously simply by suitable orientation of the osteotomy fragments. The osteotomy should be done as closely as possible to the joint; the intertrochanteric level was chosen as the most appropriate.

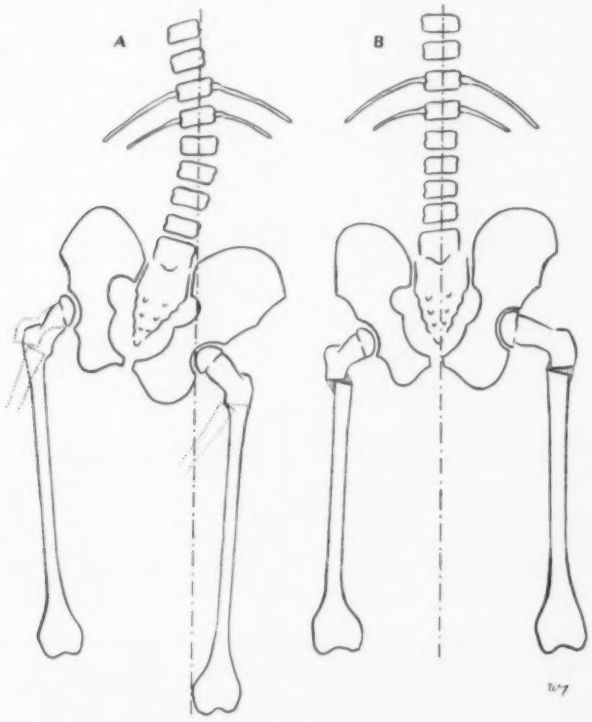

FIG. 2

Schematic drawing showing the correction of pelvic obliquity through intertrochanteric osteotomy and realignment of the lower extremities with regard to the mid-line of the body.

INDICATIONS FOR OPERATION

The indications for operation were based solely on the amount of disability. When confronted with marked disability we performed the operation regardless of the child's age, although never before the age of three years. In these severe cases the operation represented the only means to promote rehabilitation, and the possibility of recurrence with further growth had to be accepted as a calculated risk. When the disability was less marked we postponed the operation as long as

possible to minimize the risk of recurrence, keeping in mind the possible rapid development of structural changes in a growing child. The final decision as to the time for operation rested on the progression of the disability.

In patients with involvement of both limbs (the majority had bilateral deformities), the decision whether one or both sides had to be operated on rested on the degree of fixation of the hip contractures and the related disability. If only one side was fixed, the fixed side was brought into alignment and the mobile side then aligned itself spontaneously, at least partly. In patients with marked disability and deformity resulting from bilateral fixation, both sides were operated on, with a short interval between procedures. In patients in whom one side was

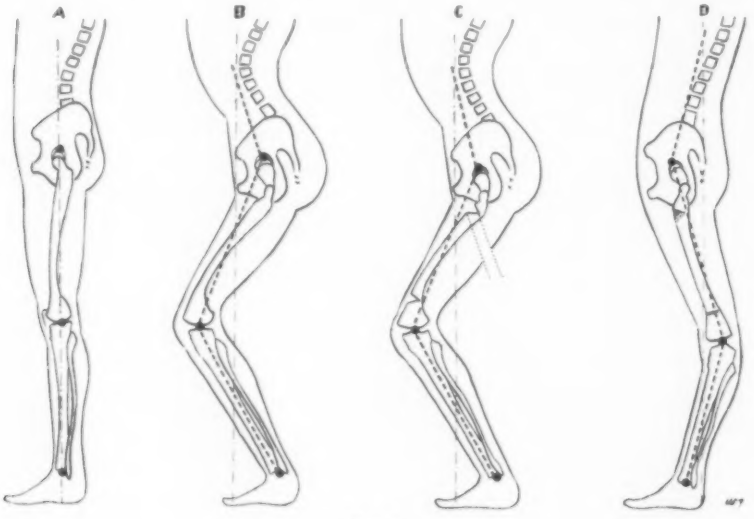

FIG. 3

Schematic drawing showing the correction of the associated flexion contracture, according to the principle of passive stability of Putti. *A* shows a normal body in which the line of gravity passes through the centers of the hip, knee, and ankle joints. *B* shows flexion contractures. Here the line of gravity passes in front of the center of the hip, behind the center of the knee, and in front of the center of the ankle. The limb folds under the weight of the body and collapses. *C* points out the levels of intertrochanteric and supracondylar osteotomies. *D* illustrates the body after completion of the osteotomies. Here the line of gravity passes behind the hip, in front of the knee, and behind the ankle. This alignment assures stability because the lower extremity cannot fold under the weight of the body.

fixed in deformity and the other was still somewhat mobile and reducible, the fixed side (usually the abducted one) was operated on first, the other operation being postponed until further disability necessitated treatment. The improvement seen after the unilateral operations done in this way has warranted the postponement, but it is quite likely that the operation on the contralateral side will have to be performed in the future in most of these patients.

TECHNIQUE OF OPERATION

The operation is essentially a simple intertrochanteric osteotomy. The alignment of the osteomized fragments is adjusted to accomplish the following:

1. To correct abduction or adduction: the proximal fragment is left in its fixed abducted position and the distal fragment and the extremity are placed in correct alignment with respect to the mid-line of the body (Fig. 2).

2. To correct flexion: the proximal fragment is left in flexion; the distal frag-

ment is placed in *hyperextension*. This point is of major importance and is therefore stressed. In contrast to the deformities in the coronal plane which need only to be corrected, the flexion deformity must be overcorrected to afford stability. The aim here is not only to correct an existing deformity but to provide passive stability to a paralyzed limb by appropriate alignment of the hip, knee, and ankle joints in relation to the gravity line according to the principle of passive stability of Putti (Fig. 3).

3. To correct valgus of the femoral neck: the proximal fragment is placed in the desired amount of varus.

4. To correct anteversion of the neck: the proximal fragment is rotated inward with respect to the shaft to produce the needed amount of retroversion.

5. To correct subluxation when present: this is accomplished by abduction and rotation of the proximal fragment to correct valgus and anteversion.

Since all these corrections may have to be performed simultaneously the following technique was used.

A preliminary technical detail is of importance. The usual orthopaedic or fracture table does not permit hyperextension of the hip. To gain the hyperextension of the hip needed in this procedure the pelvis, trunk, and head must be elevated sufficiently to transform the normal range of extension allowed by the table into one of hyperextension. A supplementary small pelvic support was designed to fit on top of the perineal post. The head and trunk were elevated on two boxes or pillows. With these modifications the patient was well above the level of the table and the foot pieces had to be elevated accordingly. After osteotomy there was ample room to lower the foot piece, thus bringing the leg into hyperextension (Fig. 4-A).

When the patient is first strapped on the table, the trunk is aligned with the table but the hip is left in the position of deformity (flexion and abduction or adduction) and also rotated internally.

A longitudinal incision is made over the lateral aspect of the greater trochanter and upper part of the thigh. The iliotibial band is split and the trochanteric prominence is identified. The vastus lateralis is split longitudinally for eight to ten centimeters distal to its origin and elevated together with the periosteum. The anterior half of the muscle is cut transversely at its origin to facilitate the insertion of a thin elevator against the medial aspect of the femur above the lesser trochanter. This elevator serves as a guide for the direction of the osteotomy. Starting slightly below the trochanteric prominence, the bone is cut transversely through to the previously inserted elevator. The medial cortex is cut just above the lesser trochanter.

Before the osteotomy is completed two Steinmann pins are inserted, one above and one below the osteotomy. The first one is directed into the greater trochanter, deep enough to give a good hold on the proximal fragment; the second is inserted into the shaft after a hole has been drilled in the lateral cortex. The medial cortex is not drilled and the hole is started on the anterolateral aspect of the shaft and directed downward so that after subsequent external rotation of the distal fragment this pin will be brought into the horizontal plane as the proximal one. The osteotomy is then completed and the fragments aligned in the desired position. An assistant loosens the foot piece at this point and brings the leg down into as much extension as possible. This corrects flexion and puts the leg in hyperextension. By further maneuvering of the foot piece, the extremity is adducted or abducted as necessary to correct the abduction or adduction deformity. Finally, the limb is rotated externally so that the foot is vertical, thus correcting anteversion since the limb was placed in internal rotation at the start of

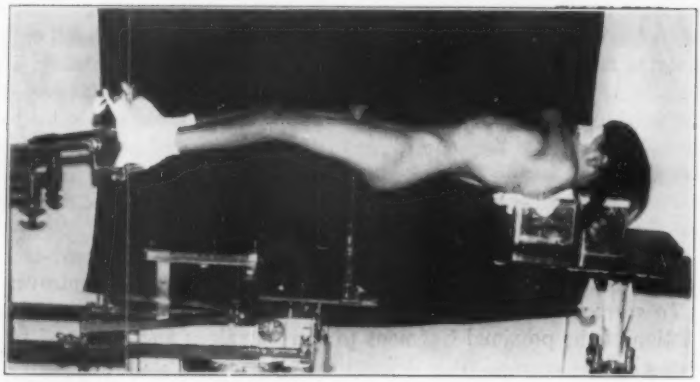

FIG. 4-A

Photograph of a patient on the operating table. The perineal post has been elevated by a supplementary post on top of the usual one, and the trunk has been elevated accordingly on two boxes.

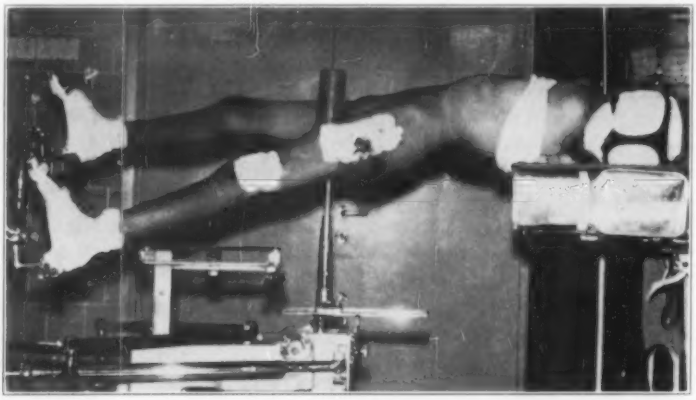

FIG. 4-B

After subtrochanteric and supracondylar osteotomy, the lower extremity is hyperextended at the hip and knee. During the setting of the plaster cast, a slight pressure will be made on the thigh.

the operation. During all these maneuvers the surgeon controls the position of the fragments by means of the two Steinmann pins. Control of the proximal fragment is particularly important because of its tendency to displace into too much varus. To avoid this, the pin in the proximal fragment is displaced slightly in a caudad direction and the pin in the distal fragment is pushed medially to displace the shaft slightly in a medial direction with respect to the proximal fragment.

An anteroposterior roentgenogram is now made and closure of the wound is started. The position, as shown by roentgenogram, is considered satisfactory when the full length of the neck is visible (anteversion corrected), the neck-shaft angle is correct (valgus corrected), any subluxation of the hip is reduced, and the distal fragment is displaced medially. If any one of these criteria is not fulfilled, the alignment is corrected by further maneuvering the Steinmann pins or the limb, as necessary (Fig. 4-C).

After closure of the wound a plaster spica cast is applied, incorporating the Steinmann pins. During this procedure and while the plaster is setting, the proximal pin is pushed in a caudad direction and the distal pin is pushed medially to maintain the desired position. A final roentgenogram is made after the patient

FIG. 4-C

FIG. 4-D

Fig. 4-C: Control roentgenogram made during operation showing the level of the osteotomy, the two Steinmann pins, and the degree of displacement.
Fig. 4-D: Control roentgenogram made after operation, with the patient in a plaster spica.

is in the cast and off the fracture table. This roentgenogram should include the whole pelvis, thus showing the over-all correction (Fig. 4-D). When correctly inserted, the Steinmann pins afford excellent fixation of the fragments.

The Steinmann pins are extracted four to six weeks after operation, depending on the amount of callus seen on the roentgenogram. The plaster spica is removed eight to ten weeks after operation, and the patient is given physical therapy to complete his rehabilitation.

Ancillary Procedures

Concomitantly with the intertrochanteric osteotomy, two ancillary procedures were performed with some frequency. In the first of these procedures, which was used when the flexion contracture was 60 degrees or more, the iliotibial band was divided. With one exception this was done through the same incision as the osteotomy. To avoid endangering the stability of the hip, the deeper soft tissues, especially the periarticular structures, were not divided. The one exception was the hip in Case 8 in which the muscles were stripped from the ilium because the flexion contracture was 90 degrees. This procedure was done through a separate incision. The capsule and two heads of the rectus femoris were left undisturbed to help preserve stability of the joint and control the position of the proximal fragment. The stripping corrected about one-third of the flexion contracture in this hip. The rest of the deformity was corrected at the osteotomy site.

The second ancillary procedure, supracondylar osteotomy, was performed on all patients in whom there was a flexion contracture of the knee, even a very slight one. In only two patients in this series was a supracondylar osteotomy not done. In one (Case 5) the knee could be fully extended and even slightly hyperextended before operation. In the other (Case 9) the left knee showed 20 degrees of recurvatum before operation. In all other patients flexion contractures varying from 10 to 45 degrees were present. Osteotomies were performed in these even when the power of the extensors of the knee was fair (Case 4). It is difficult to understand why a flexion contracture should develop in a knee with this degree of extensor power. However, we have seen this definitely develop in other cases not reported here; we think that this may happen because of flexion contracture of the ipsilateral hip, which encourages shortening of the knee flexors.

It may be worth while to mention that in about one-third of the patients

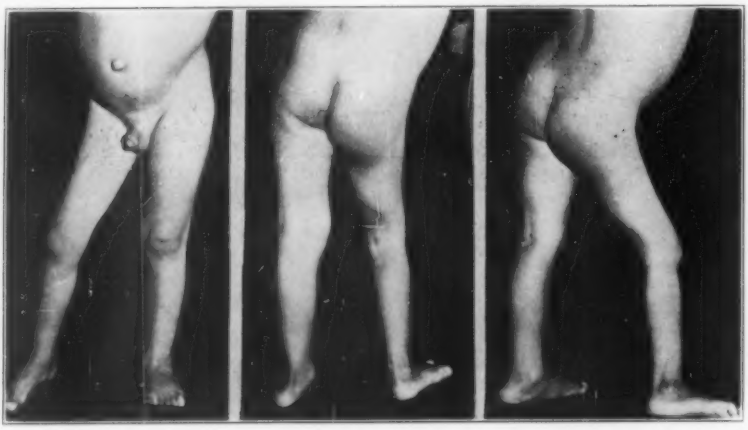

FIG. 5-A

Figs. 5-A through 5-D: Case 1, a boy with paralysis of the right lower extremity. There is fixed pelvic obliquity due to abduction contracture of the right hip.
Fig. 5-A: Photographs made before osteotomy.

FIG. 5-B

Preoperative roentgenogram of the pelvis.

in this series release of the iliotibial band at the knee together with fasciotomy at the hip had been performed previously. These procedures did not prevent recurrence of the contracture.

The presence of even a slight flexion contracture of the knee (10 degrees) was considered an indication for correction. In accordance with the principle of passive stability (Fig. 3), the knee must be in a slight degree of recurvatum. This can usually be achieved by an incomplete transverse osteotomy, leaving the posterior cortex intact to break when the knee is subsequently manipulated into the corrected position. Only in marked flexion contractures is it necessary to remove a small anterior wedge. The incomplete supracondylar osteotomy is performed at the same session, immediately after the intertrochanteric procedure. During the setting of the plaster cast, slight pressure is exerted on the anterior aspect of the knee to put it in the desired position of about 10 degrees of recurvatum, an amount sufficient to assure passive stability yet not produce any disability. The extent to which this optimum amount of recurvatum can be exceeded in either direction depends on the balance existing between the extensor and

FIG. 5-C

Photographs made two years after operation. At this time, the child walked freely, but used a cane for outdoor activities.

FIG. 5-D

Roentgenogram made two years after operation.

flexor muscles of the knee. In the presence of strong flexors and weak or absent extensors a greater degree of recurvatum may safely be desirable, because with continued growth it will most certainly diminish. The reverse situation, however, when the flexors are weak or absent, commands extreme care in keeping the optimum angle of 10 degrees or even less. This is particularly important when there are strong extensors and weak flexors, but it applies also to the totally paralyzed knee. In the presence of normal muscle power in both flexors and extensors, the flexion contracture only is corrected and the knee is put in full extension (180 degrees) with no recurvatum at all.

COMPLICATIONS

There were no complications in the immediate postoperative period. One

FIG. 6-A

Figs. 6-A through 6-E: Case 8, a girl with paralysis of the trunk and both lower extremities. There is fixed pelvic obliquity—the right hip is in abduction, the left hip is in adduction and subluxation, and both are fixed. Osteotomy of both hips was performed.

Fig. 6-A: Photographs made before operation. At this time, the child could not walk or stand and was confined to a wheel chair.

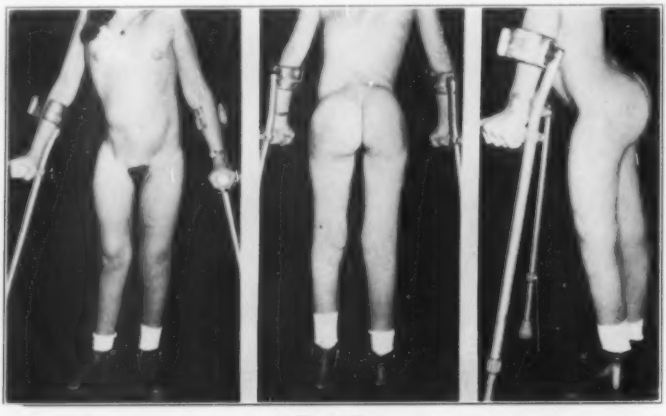

FIG. 6-B

Photographs made two and a half years after operation. At this time, the child could walk unrestrictedly with two leg braces and elbow crutches and could manage a few steps with crutches alone.

patient (Case 2) sustained a fracture at the site of the osteotomy some time after she resumed walking. For reasons unknown she did not report the fracture immediately. It was detected at a routine follow-up visit a few weeks later, when union in marked coxa vara was already present. She was operated on again and the neck-shaft angle was corrected. Since she was a patient with unilateral involvement, her unrestricted activity may have been responsible for this complication. We have since imposed very strict rules regulating the amount of activity after operation.

FIG. 6-C
Roentgenogram of the pelvis made before operation.

FIG. 6-D
Roentgenogram made two years after operation.

FIG. 6-E
The range of motion in both hips and knees is normal two and a half years after operation.

RESULTS

When assessing the results of treatment in fixed pelvic obliquity, many factors must be considered. First of all, one should keep in mind that this is a deformity superimposed on the basic paralytic involvement. The results may be assessed only in terms of lessening of the over-all disability. In this study the locomotor disability caused by the fixed pelvic obliquity was evaluated on the

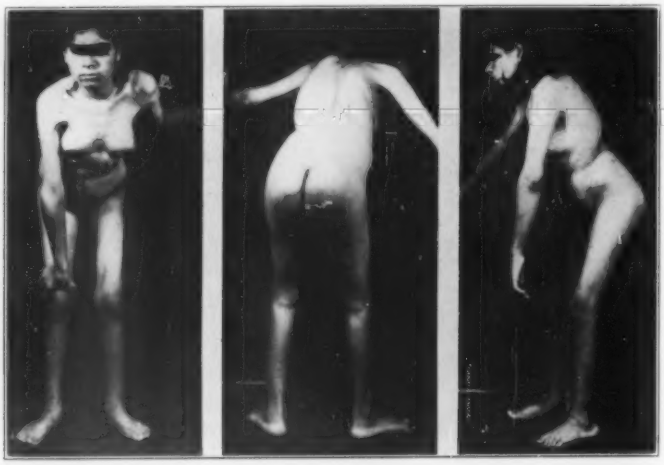

FIG. 7-A

Figs. 7-A through 7-E: Case 12, a girl with paralysis of both lower extremities. There is fixed pelvic obliquity—the right hip is in adduction and subluxation, the left hip is in abduction, and both are fixed. Osteotomy was performed on both hips.

Fig. 7-A: Photographs made before operation. The patient is unable to stand or walk when deprived of external support; even with the aid of braces and crutches, her locomotor activity is much restricted. Note the typical hand-on-thigh posture.

FIG. 7-B

One and a half years after operation, the patient could stand and manage a few steps unaided; however, she used crutches and one brace for unrestricted outdoor activities.

basis of three categories: (1) walking ability and need for support, (2) the type of apparatus used, and (3) the amount of activity possible (Table I). The patient's rating in each of these categories was given a numerical grade.

The over-all rating was calculated as the sum of the grades in each category. The results of treatment were estimated in a roughly quantitative fashion as grades

FIG. 7-C

Roentgenogram of the pelvis made before operation.

FIG. 7-D

Roentgenogram of the pelvis made one and a half years after operation.

FIG. 7-E

The range of motion in both hips and knees is normal one and a half years after operation.

of improvement, which were calculated by subtracting the sum of the patient's numerical grades in the three categories before operation from the corresponding sum of the numerical grades after operation.

The quantitative assessment of the degree of correction of the pelvic obliquity, the postoperative function of the hip and knee, the stability of the knee, and the amount of shortening of the limbs were also evaluated in the results.

All the data pertaining to the patients in this series may be found in Table I. The results can be summed up as follows.

Decrease of Disability

With the exception of one patient, all showed a more or less marked degree of improvement: two were improved (Grade 2 to 3), eight were much improved (Grade 4 to 5), and two were very much improved (Grade 6 to 7).

Improvement graded as 2 to 3 signified increased walking ability and increased activity. One patient, nine years old, with unilateral involvement (Case 3) was restricted in her activity before operation because of frequent falls and an awkward gait in which she held her hand against her thigh. Another patient, aged twenty years (Case 5), with bilateral involvement was practically unable to walk outside her home before operation because of frequent falls. After operation both patients discarded their braces. The postoperative improvement in these two patients received almost identical grades—3 for the first and 2 for the second patient, this despite very different functional abilities. Case 3 regained normal walking ability and unrestricted activity, whereas Case 5 was still partly restricted. The similarity in rating of improvement was due to the fact that the extent and degree of paralytic involvement were quite different in each of these patients (Table I). Thus, numerically identical improvements might represent very different levels of functional ability.

Improvement graded as 2 to 4 signified increased walking ability, increased and often unrestricted activity, and less dependency on supporting apparatus. More than half of all the patients in this series showed this amount of improvement (Figs. 5-A through 5-D and 7-A through 7-E).

Improvement graded as 6 to 7 presented essentially the same features as grades 4 and 5, but the amount of improvement was greater in comparison with the preoperative condition. Special mention should be made of one patient (Case 8) who was confined to a wheel chair before treatment, but is now able to walk more than a mile with the aid of braces and elbow crutches and has unrestricted activity (Figs. 6-A through 6-E).

Correction of Pelvic Tilt

The pelvic tilt was corrected entirely in twelve of the thirteen patients. In the thirteenth patient there was only partial correction.

Mobility of the Hip and Knee

The function of the hip and the knee was normal in all our patients. Some limitation of movement was present, particularly at the knee, for a variable period after the spica was removed, but gradually all movements returned to their normal range. In some patients this was achieved in a few weeks; in others, in a few months.

Stability of the Knee

This was achieved in every instance. A stable knee may be defined as a knee with no lateral instability that extends on weight-bearing to full extension, or

to 10 degrees of hyperextension at the most, either by active muscle power or by passive stability as defined previously. Excessive recurvatum was found at follow-up in a patient (Case 9) who had 20 degrees of recurvatum before operation and the same amount after operation.

Shortening

In three of the four patients with unilateral involvement, shortening of the extremity occurred, amounting to two centimeters in one and to one centimeter in each of the other two.

DISCUSSION

Subtrochanteric osteotomy was advocated by Jones for the treatment of paralytic dislocation of the hip, and intertrochanteric osteotomy was advised by Müller to improve the mechanics of the paralytic hip. In both instances treatment was directed to the paralyzed hip without considering its relation to the pelvis or to the body as a whole.

The osteotomy proposed by Irwin and applied in two illustrative cases served a different purpose. In the first case, a subtrochanteric osteotomy of the adducted femur in a patient with fixed pelvic obliquity increased the length of this apparently short limb and shifted the femur under the oblique pelvis beneath the center of gravity. In the second case, a previous spine fusion in the position of deformity contra-indicated correction of the adducted femur; hence, the abducted femur was brought into a weight-bearing position by an osteotomy at the junction of the middle and upper thirds. This, in effect, converted the upper third of the shaft into a femoral neck and adducted the rest of the shaft into a position where it could bear weight. In both cases the pelvic obliquity was not corrected.

The method we used resembles that of Irwin since its objective is to bring the lower extremities into a weight-bearing position underneath the pelvis. However, by choosing a higher level for the osteotomy, by performing it on both hips when both are contracted, and by purposefully aligning the osteomized fragments, several goals were achieved simultaneously.

First, alignment of the lower extremity or extremities in relation to the body corrected the pelvic obliquity, as defined previously. Second, by correction of the concomitant flexion contracture, passive stability, as advocated by Putti, was made possible. Third, the intrinsic deformity of the paralytic hip (valgus, anteversion, and subluxation) was dealt with simultaneously.

By this relatively simple procedure the essential problems of the paralytic hip can be dealt with, although ancillary procedures may be necessary. A number of our patients had had fasciotomies of the iliotibial band a few years previously, but these procedures did not prevent recurrence of the contractures. It is our belief that although these soft-tissue operations are valuable, they cannot correct fixed pelvic obliquity unless they are so extensive that they may compromise the stability of the hip. In this series we have occasionally performed fasciotomy of the iliotibial band as an ancillary procedure at the time of osteotomy in patients with marked flexion contracture.

Supracondylar osteotomy for flexion contracture of the knee was used in nearly every instance. Almost all our patients had a concomitant flexion contracture of the knee. It is quite obvious that these ancillary procedures had no bearing on the correction of pelvic obliquity.

There are several possible disadvantages to these osteotomies. A unilateral osteotomy producing varus of the femoral neck causes shortening of the ex-

tremity. This has not been a significant problem in this series. Even in a patient with unilateral paralysis whose already shortened leg is further shortened by one or two centimeters, the stability achieved through the operation and the resulting lessening of the over-all disability more than compensate for the additional shortening. Significant shortening could be dealt with by one of the leg-equalization procedures, if need arose.

Recurrence of the deformity with growth must be anticipated in all children who are operated on at a young age. So far we have not seen a recurrence, but should one occur and necessitate a second operation, the intervening years with lessened disability would have made possible the utmost rehabilitation, and the operation would have served a useful purpose.

We have not seen avascular necrosis of the proximal fragment following intertrochanteric osteotomy even in the young patients. Search of the available literature did not disclose any mention of this complication, even in Müller's large series. However, the risk of such an occurrence cannot be denied.

Because of the short follow-up and possible future complications it should be emphasized that this must be considered a preliminary report.

SUMMARY

Fixed paralytic obliquity of the pelvis occurs when the pelvis is held in an oblique position by contracture both above and below the iliac crests with an abduction contracture in one hip, an adduction contracture in the other hip, and scoliosis. The major ensuing disability is difficulty in locomotion.

We believe that the contractures below the pelvis are the main deformity and are primarily responsible for the disability. Once they are corrected, the pelvis can return to its normal position and lessening of the disability results. Any remaining scoliosis is then not dependent on the pelvic obliquity and can be dealt with separately.

Intertrochanteric osteotomy of one or both hips is the best method to achieve this correction. With one procedure it is possible to deal with flexion contracture or subluxation of the hip as well as anteversion of the femoral neck.

Thirteen patients are reported on whom this operation was performed. In all instances after operation these patients had less locomotor disability and increased functional ability to a notable and sometimes remarkable degree.

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Skin Arthroplasty of the Hip

An Experimental Study in Dogs*

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The history of the development of arthroplasty has spanned two centuries since the resection of a shoulder joint was described by White in 1769. The joint resection of Syme, the pseudarthrosis of Barton [44], the capsular flap of Ollier, the fascial pedicle of Helferich, the heterotopic membranes of Föderl, and the free fascial transplants of Kirschner formed the basis for the progress made by Baer, Murphy, Putti, Henderson, Campbell, and others in the clinical use of arthroplasty. Development of a non-reactive metal by Venable and associates shifted emphasis from interposition of soft tissues to use of rigid inert materials, introduced by Smith-Petersen and, more recently, led to replacement of articular parts. The premise of the present investigation is that an ideal method of arthroplasty has not yet been devised. An arthroplasty performed without sacrifice of substance which provides a living articular surface is an incontrovertible ideal. Whether this can be achieved remains to be seen.

A physical barrier to union has long been accepted as a necessary condition for re-formation of a movable joint. The materials that have been employed for this purpose have been legion and sometimes improbable. The deep implantation of skin for other purposes, such as the repair of herniae, defects of ligaments and tendons, and cosmetic deformities, is well documented. It is surprising that the use of autogenous skin as an interposed material in arthroplasty has received only cursory notice until the last decade.

Loewe [25] first reported extensive use of skin in reconstructive surgery of tendons and fascia. Rehn [40], Peer and Paddock [36], Uihlein, Cannaday, and many others have extended its use and described the fate of deeply implanted skin. Gluck, according to Murphy [30], was the first to use skin in arthroplasty, in 1902. In 1929, Loewe [26] wrote of interposition of skin between the ends of bone in the subtrochanteric osteotomies of two patients. Rehn [41], in 1934, suggested its use but did not report a specific application. The earliest systematic use of the technique of interposition of skin in arthroplasty was made in Italy. Pais, in 1948, reported insertion of free full-thickness grafts of skin into the finger joints of three patients. Pasquali, in 1950, described the use of free full-thickness skin in the reconstruction of both hips of a patient. These reports were followed by those of Logroscino, Fiume, and Delchef and his associates. E. Kallio and K. E. Kallio reported the largest clinical experience with the use of skin in arthroplasty. In the United States the method has had limited use. Brown and associates first used the technique of cutis arthroplasty in 1949 and reported four cases in 1958. These authors regarded the results as at least comparable to those by other methods of arthroplasty, and they found that the skin satisfied the biological and physical requisites for joint tolerance, adaptation, and function.

Experimentation with skin arthroplasty in animals has been scant, having been reported only in the European literature, by Peregalli, de Marchi and

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Gambier, and Kettunen. The capacity of primitive connective tissue for differentiation in response to environmental stimuli has been well established by the work of Maximow and Peer. Krompecher demonstrated that cartilage may be produced by mesenchymal metaplasia in response to pressure stresses *in vitro* as well as *in vivo*. Dermis is known to be a rich reservoir of undifferentiated connective tissue. The demonstrated capacity of dermis to undergo conversion to tissue that resembles tendon and fascia has fostered the hope that the same potential may exist with relation to joint cartilage. The most optimistic opinion expressed in this regard was that of Kettunen [21], who observed the formation of new hyaline cartilage which he believed had its origin, at least in part, in the dermal mesenchyme.

The object of this study, therefore, was to determine the fate of skin after its implantation within a joint of a dog, and its role in the formation of a new articular surface.

MATERIALS AND METHODS

Both hips of each of thirty adult mongrel dogs were used. Each hip joint was done at a separate operation. The second operation was done after complete recovery from the first, and it was scheduled in such a way as to provide different lengths of observation for each hip. Dogs were selected without regard to sex; their weights were between ten and fifteen kilograms. The care of the dogs followed the kennel routine. They were confined to cages for one month after operation but thereafter were permitted greater freedom.

Anesthesia for surgery was produced by intravenous injection of pentobarbital sodium. Hexachlorophene detergent (phisohex) was used for skin antisepsis in preparation of both the operative area and the graft. Except in one instance, a single injection of 600,000 units of procaine penicillin and 0.5 gram of streptomycin was given after operation.

A total of fifty-three joints were subjected to arthroplasty by interposition of skin. Four joints were treated in an identical manner, but the skin was omitted. Three joints were surgically dislocated and simply replaced to test the effect of severance of the ligamentum teres upon viability of the femoral head. Of ten hip joints, all of which were exposed through a lateral surgical approach, six became dislocated postoperatively and, as will be discussed later, served as fortuitous controls. A medial approach to the hip joint averted this problem thereafter. Since it was recognized that the pathological processes for which arthroplasty is done in human beings could not be duplicated, the alternative of producing conditions as nearly ideal for arthroplasty as possible was adopted. The cartilage and subchondral bone of the femoral head were removed completely, the acetabulum was left untouched. Fresh, unmodified, autogenous skin was used for implantation after it had been scrubbed for ten minutes with hexachlorophene detergent. Three types of graft were used: full-thickness skin, the dermal layer of skin after removal of the epidermis with a Padgett dermatone, and the epidermal layer obtained by the same method. Grafts were placed over the femoral heads with the skin oriented in an upright or inverted position in about an equal number of times. The skin membrane was fitted over the femoral head and secured by a loosely tied circumferential suture of stainless-steel wire. In twenty cases plaster immobilization was provided for two weeks. The results were not affected by this measure. Animals whose limbs were not supported tended to immobilize voluntarily the limbs operated on for about an equal length of time.

Each dog was observed for a period of two weeks, was re-examined one month after operation, and was studied again prior to its being killed. Observations

TABLE I

SKIN ARTHROPLASTY IN DOGS:
TIME OF OBSERVATION AFTER ARTHROPLASTY

Technique	1 wk.	2 wks.	1-4 mos.	4-8 mos.	8-12 mos.	18-24 mos.	Total
Full-thickness graft	1	1	6	5	5	4	22
Dermal graft	1	1	4	5	4	3	18
Epidermal graft			2	2	3		7
Control: no skin graft			1	1	2		4
Control: simple dislocation			1	2			3
Postoperative dislocation			1	1	4		6
Total	2	2	15	16	18	7	60

included roentgenographic examination one month after operation and another at the time of death, evaluation of the functional recovery of the limb operated on, and post mortem examination. The animals were killed at intervals varying from one week to two years (Table I). After each animal was killed, the joints to be examined were removed intact and inspected grossly for evaluation of the quality of the articular surface, evidence of grossly recognizable residue of implanted skin, and signs of epidermal cysts. The specimens were then quickly frozen, and a thin section of each joint was cut with a band saw. The section was preserved in formalin and decalcified with formic acid. Paraffin sections were made, and these were stained with hematoxylin and eosin and with van Gieson stains.

Each of the microscopic sections was studied to determine the fate of the implanted skin and to assess the contribution of the skin to re-formation of the articular surface. (In several instances hyaline cartilage of normal appearance was recognizable about the periphery of the femoral head. That this was cartilage that had escaped removal was readily apparent by its sharp demarcation from the subchondral bone, its regular arrangement of cells, and the homogeneity of its matrix. In no case was cartilage of this appearance considered to be a product of the experiment.)

RESULTS

Of forty-seven hip joints within which skin had been interposed and joint integrity preserved, thirty-nine retained good function. Function was considered to be good when the animal was able to walk or run without a limp or apparent pain, and when motion of the joint, measured with the animal under general anesthesia, was free through a range of at least 75 per cent of the normal in all planes. Animals with satisfactory function began to use the limb operated on in walking within two or three weeks after operation, and they continued to show improvement for about four months. Thereafter, function remained constant, without apparent deterioration, during the period of observation. Of the eight animals with unsatisfactory function, all carried the limb operated on, and did not use it for bearing weight, and in each instance limitation of motion increased, often to nearly complete immobility. Functional recovery could not be related to the type of arthroplasty, and it occurred as well in the absence of implanted skin. Infection was present in a single instance in which antibiotic protection was unintentionally omitted. No deaths occurred.

The roentgenographic appearance was unrelated to the type of graft used.

The joint space appeared narrow after one month but regained width after six months. In instances in which the intact epithelial surface of the graft had been placed in contact with normal acetabular cartilage, destruction of the cartilage was consistently observed. In some instances extensive subchondral erosion had developed.

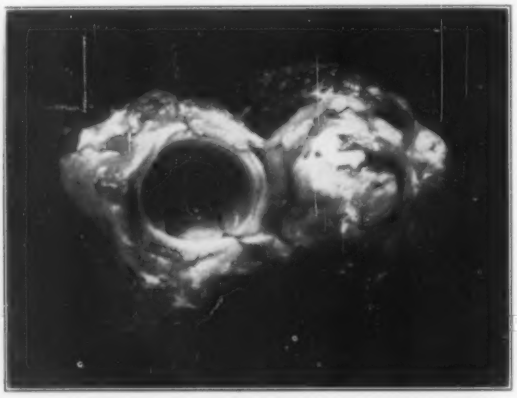

FIG. 1

Left hip. Dermal graft examined at two weeks. The bone of the femoral head is denuded at the upper surface, but elsewhere the graft remains and is loosely attached to bone.

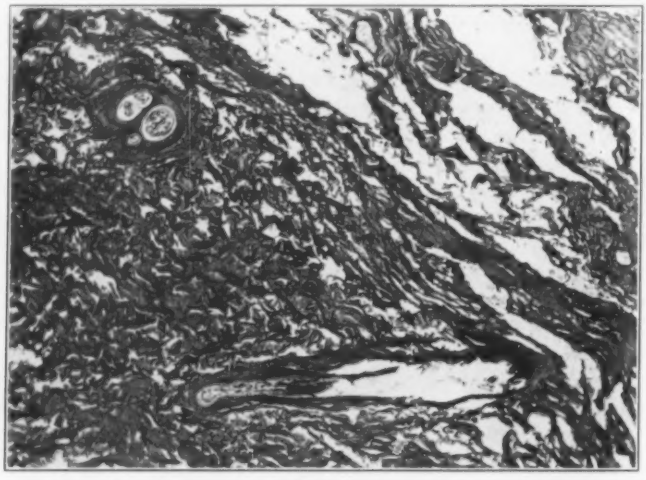

FIG. 2

Right hip, examined at five months, showing appearance of the residual skin about the neck of the femur. Note the degenerating hair follicles within the disordered, sparsely cellular collagenous tissue (hematoxylin and eosin, van Gieson; ×70).

Necrosis of bone of the femoral head occurred in two instances. In all others, cells of both bone and marrow remained viable in appearance. Formation of new bone within the femoral head was limited to the re-formation of the subchondral plate, except in the two instances of gross infarction, in which the process of creeping substitution was observed.

The operations are listed in Table I according to type and length of observation.

In joints examined after one week, each type of graft was found to be intact, but none was fixed to the surface of the femoral head. At two weeks a defect had developed in the skin membrane at the site of maximum articular pressure (Fig. 1). In joints in which the skin had been placed with the subcutaneous surface adjacent to the denuded bone, a tenuous attachment had developed.

FIG. 3

Left hip, examined one month after insertion of the dermal graft. Densely cellular fibrous tissue has formed over the exposed bone at the margin of the head. Note the inclusion of a hair shaft (hematoxylin and eosin, van Gieson; ×85).

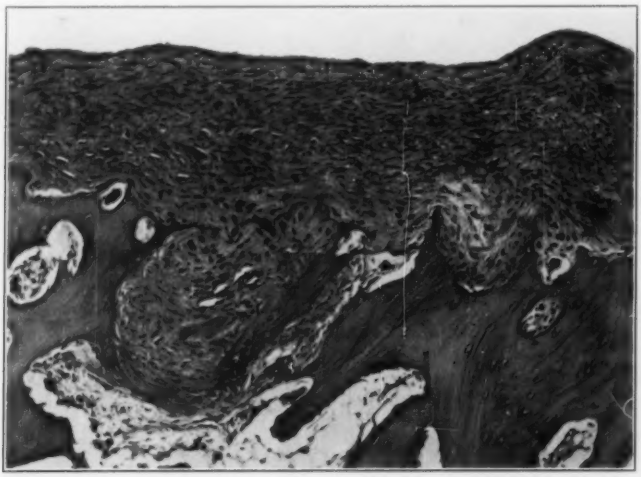

FIG. 4

Left hip, examined one month after the removal of cartilage but without the implantation of skin. This control animal showed formation of proliferating fibrous tissue covering the margin of the head similar to that noted in the experimental animal of Fig. 3 (hematoxylin and eosin, van Gieson; ×100).

Examination at the end of four weeks showed gross destruction of the implant, regardless of the method of implantation. The bone at the region of major stress had become eburneous. A cuff of dense fibrous tissue was present about the

neck at the base of the femoral head. Often a free border of this tissue lay between the articular surfaces at the periphery in the form of a meniscus. This was readily recognized as a residue of skin by the microscopic appearance of sparsely cellular, fragmented, wavy collagenous material interspersed with remnants of skin appendages (Fig. 2). Although the glands of the skin had disappeared, hair

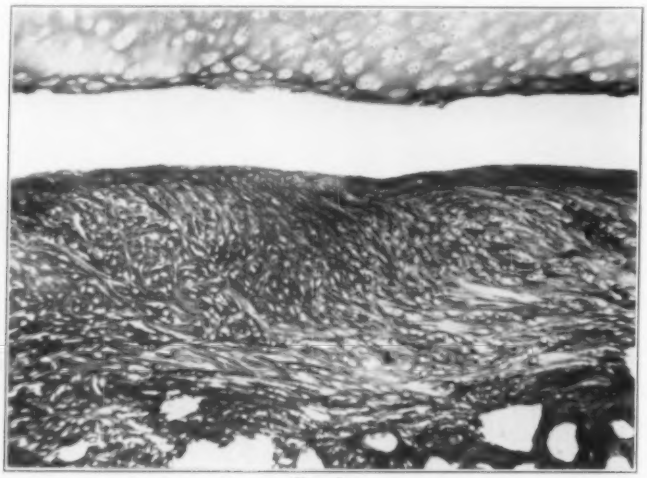

FIG. 5

Left hip, examined five months after implantation of full-thickness skin. The newly formed fibrous tissue covering the articular surface is undergoing cellular changes, with formation of lacunae. The stroma remains fibrous. Note the apposing normal acetabular cartilage (hematoxylin and eosin, van Gieson; ×80).

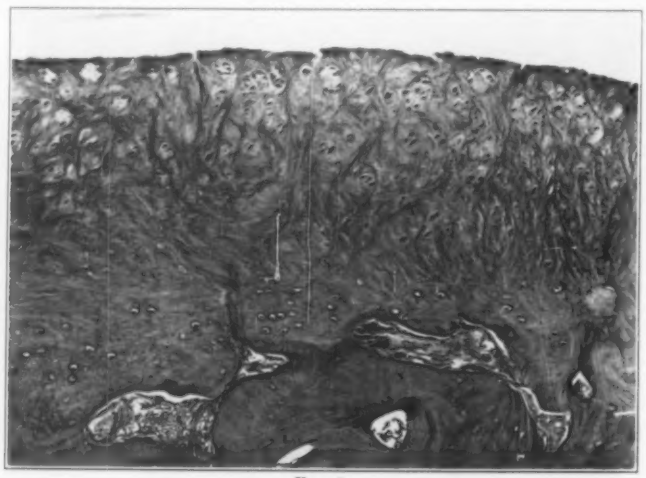

FIG. 6

Right hip, examined seven months after implantation of the dermal layer of skin. The cells have all assumed a lacunar location, with grouping of the cells and beginning hyalinization of the surrounding matrix (hematoxylin and eosin, van Gieson; ×100).

follicles remained in abundance. Islands of epithelial cells remained, and in joints in which epidermis had been implanted, microscopic epidermal cysts were invariably present. The lack of inflammatory reaction about the remnants of epidermis and its appendages was remarkable.

The articular surface at four weeks consisted of denuded trabecular bone, except at the periphery, where there was usually a covering of densely cellular fibrous tissue (Fig. 3). This tissue appeared to be intimately related to the connective tissue of the intertrabecular spaces; it was continuous with the peripheral cuff of dermal remnant, but the only resemblance to any portion of the implanted

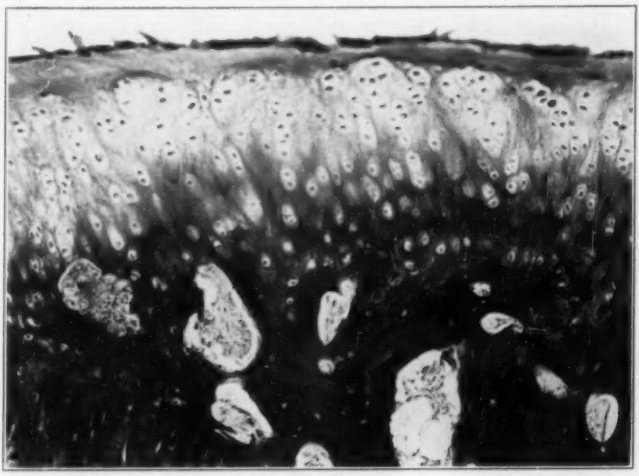

FIG. 7

Left hip, examined twelve months after implantation of the dermal layer of skin. Further evidence of cartilaginous metaplasia has developed, with columnar orientation of the lacunae and re-formation of the subchondral bone plate (hematoxylin and eosin, van Gieson; ×135).

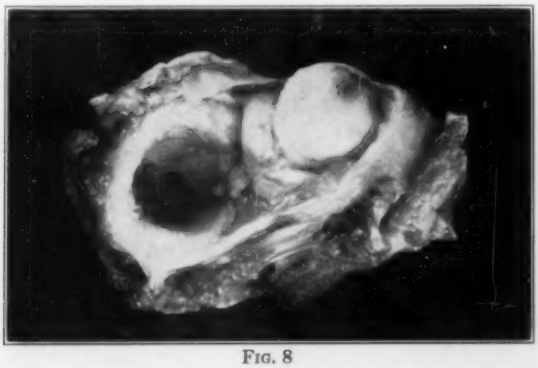

FIG. 8

Right hip, examined twenty months after insertion of the dermal graft. There is complete coverage of the femoral head by white opaque material.

skin was the occasional inclusion of remnants of hair within the proliferating tissue. The temptation to assume that this tissue had its origin from skin was tempered by the finding of similar newly formed fibrous tissue in control joints in which cartilage had been removed but no skin had been implanted (Fig. 4).

Joints examined four to eight months after arthroplasy (and later) were strikingly similar whether or not skin had been implanted and regardless of the type of implantation. The region of maximum pressure had become eburneous, but elsewhere there was progressive coverage of the femoral head by irregular, mottled, opaque tissue. Cellular changes became apparent within this tissue about six months after operation (Fig. 5). The cells lost the elongated configuration of

fibrocytes, became round or oval, and lay within lacunae. Often the cells were paired, and a suggestion of columnar arrangement was evident (Fig. 6). The matrix remained fibrous, with strands running generally parallel to the articular surface but seeming to branch from fibers of the marrow spaces.

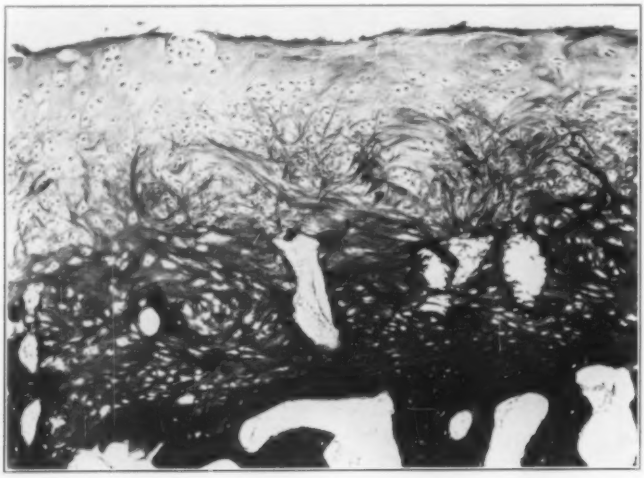

FIG. 9

Right hip, examined at twenty months. This is the microscopic appearance of the femoral head shown in Fig. 8. Cartilaginous metaplasia has become complete, with well formed lacunae, hyalinization of the matrix near the articular surface, and re-formation of the subchondral plate. Note the orientation of the fibrous strands of matrix (hematoxylin and eosin, van Gieson; ×90).

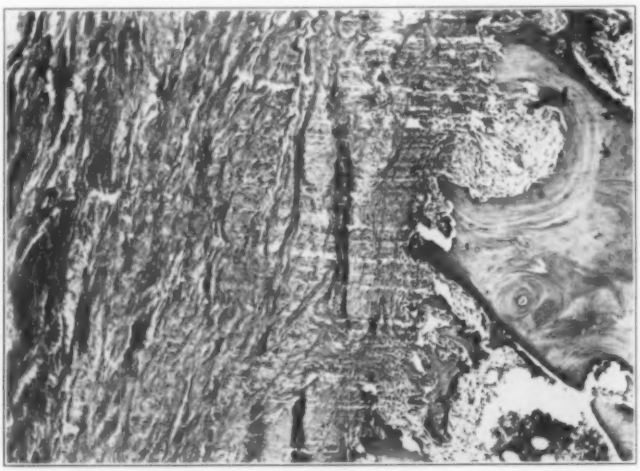

FIG. 10

Right hip, examined three months after implantation of full-thickness skin graft followed by accidental postoperative dislocation. The implanted skin membrane has become firmly attached to bone by proliferating connective tissue (hematoxylin and eosin, van Gieson; ×55).

Between eight and twelve months, the coverage of the articular surface increased. Cellular transformation and reorientation became more regular, and the superficial region of the matrix assumed a more nearly homogeneous appearance (Fig. 7). By this time, re-formation of the subchondral plate was well

advanced. As had been observed earlier, no substantial difference was recognizable among the several experimental groups that could be attributed to the presence of implanted skin or to the type of implantation.

Five of seven joints examined between eighteen and twenty-four months were functionally satisfactory, as previously defined. Each of these five joints was found to have a remarkably uniform articular surface of bluish white, opaque tissue (Fig. 8). The cellular transformation had become complete. The matrix retained a generally fibrillar appearance, but the fibrils had become finer, and in some regions the matrix presented a hyaline appearance. The fibrous strands seemed to branch from the vertically arranged fibers of the marrow spaces, creating an arborescent pattern and suggesting origin from the medullary connective tissue (Fig. 9).

Controls of several types were imposed. The obvious disintegration of the skin membrane within the first four weeks in every joint examined, and the identical appearance of the joints thereafter, regardless of the presence of skin or the type of skin graft used, obviated the need for a large number of controls. Three hip joints that had been surgically dislocated and reduced showed no evidence of avascularity attributable to severance of the ligamentum teres. In four joints from which the skin had been omitted, re-formation of an articular surface occurred in a manner indistinguishable from that of the experimental groups in animals observed for periods of one, four, eight, and twelve months after operation. Unintentional postoperative dislocation occurred in six animals. In this situation the implanted skin remained in contact with the femoral head and became fused to the cancellous bone by ingrowth of fibrous tissue from the marrow spaces; metaplasia to cartilage was not observed in this group (Fig. 10).

CONCLUSIONS

This study demonstrated that the tolerance of joints to deeply implanted skin is similar to that observed for other sites of implantation. In exception to this, epidermis seems to exert a destructive effect when it is placed in apposition to cartilage.

The fate of deeply implanted skin as described by Uihlein and by Peer and Paddock had been confirmed. The epidermal portion of the skin disintegrated rapidly while the dermal portion survived and, in the absence of articular pressure, became incorporated by connective tissue of the host.

Fresh autogenous skin of adult dogs used as interposed membranes in arthroplasty, with or without postoperative immobilization and regardless of the portion of skin used or its method of implantation, is inadequate to withstand the intra-articular stress to which it is subjected and does not survive as a weight-bearing membrane. No recognizable trace of skin remained on the articular surface after any of forty-seven technically satisfactory arthroplasties. The capacity of the osseous bed to support a graft in the absence of articular pressure was apparent in the controls, especially the six dislocated hips.

Although it was tempting to draw the conclusion that the newly formed joint surface originated from some portion of the implanted skin, there was no convincing evidence of this. The new surface seemed to stem directly from the connective tissue of the intertrabecular spaces and to be formed identically in the absence of implanted skin.

Within the conditions of this experiment, a restorative process occurs by proliferation of connective tissue of local origin. This process begins with growth of highly vascular connective tissue within the marrow spaces beneath the denuded articular surface. This newly formed tissue spreads to cover the surface of the

head of the bone by the end of twenty-four months. The articular environment evokes a transformation of fibrous tissue to a material that has the morphological characteristics of fibrocartilage. In some regions there was a tendency toward hyalinization of the ground substance, but this was a localized phenomenon within a predominantly fibrous background. Nevertheless, in its association with vertical columns of cells within lacunae, the pattern was reminiscent of normal articular cartilage.

The present findings closely resemble those reported by Phemister and Miller, in 1918, regarding the similar use of fascia lata. These conclusions are pertinent only within the conditions of this study. It is recognized, as Campbell [7] noted many years ago, that animal experimentation in arthroplasty has certain limitations and that it is not wholly reliable in estimating the value of a procedure for use in human beings.

COMMENT

Present methods of arthroplasty sacrifice the normal geometric distribution of force by distorting the relationships of the lever arms about the hip joint, and they sacrifice intrinsic stability of the hip joint by replacing the ellipsoidal femoral head with a perfect sphere. The preservation of the intricate architectural refinement of a joint in the course of its reconstruction may be impractical, but it is, nevertheless, an estimable goal.

That mesenchymal chondrogenesis occurs seems well established experimentally. It has been observed clinically by several writers [1,13,46]. In experimental arthroplasty Kettunen [21], observing the formation of new cartilage, believed it had its origin mainly in the loose connective tissue of implanted skin. Although some of the conclusions based on the present work and those of Kettunen are in diametric opposition, perhaps a more significant fact is that the experimental results were almost identical. In each study a fibrous joint surface developed, within which cartilaginous transformation occurred. We agree, furthermore, that the cartilage originates in mesenchymal tissue. The question of the source of the metaplastic tissue is debatable and perhaps immaterial, considering the ubiquity of mesenchyme. The fact that the potential of chondrogenesis from mesenchyme exists justifies continuing effort to utilize the process in the creation of new joint surfaces.

The production of conditions favorable to this event is a major challenge, since the limiting factor in clinical arthroplasty would appear to be the vascularity of the osseous bed. The basic problem is, therefore, that of providing an adequate substrate within which chondrogenesis may occur, and it is to this end that future efforts should be directed, rather than to continued search for a more suitable substance for interposition.

SUMMARY

The rationale of interposition of skin in arthroplasty was examined.

Sixty operations were performed on thirty dogs; of these, fifty-three were arthroplastic operations, with implantation of fresh autogenous skin, or a part of it, as an interposing membrane. Six hip joints became dislocated postoperatively, leaving forty-seven technically successful operations.

The animals were observed for periods of one week to twenty-four months. It was found that skin membranes did not survive within the hip joints of dogs or contribute to formation of new articular surfaces.

Progressive formation of a new joint surface was observed in most animals. This consisted of tissue that had the morphological characteristics of fibrocar-

tilage. Its formation occurred similarly with or without implantation of full-thickness skin or portions of skin.

It is suggested that the newly formed joint surface in these animals is derived from immature connective tissue, probably of local origin, and is dependent for its formation on the compressive force of the joint environment and on an adequate blood supply of the underlying bone.

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Repair of Knee Ligaments in Dogs

I. The Lateral Collateral Ligament *†‡§

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Extensive clinical experience in the treatment of injuries of the ligaments of the knee in man indicates that surgical repair of a completely torn ligament will, in the majority of cases, result in more certain recovery with less disability than will non-surgical treatment [4]. We are satisfied from our clinical experience that recovery is more complete and more rapid after surgical treatment and that good results are augmented by, and largely dependent on, early surgery. In our experience early surgical repair has given consistently better results [5]. However, we have been unable and unwilling to carry out a controlled study of paired cases treated with and without open surgical repair in the human being. Most of our patients have accepted our recommendation for surgical repair and have been able to tolerate it. The patients we treated late confirmed our opinion, since the results obtained did not equal those in patients with fresh injuries.

When this investigation was initiated, the only article we could find that seemed to bear specifically on the problem of ligamentous repair was that by Jack. However, after our experiments were under way similar work was reported by Clayton and Weir. The purpose of our experimental project was to answer the questions: (1) How do ligaments repair? (2) What circumstances are most favorable for the process of repair? and (3) How do these circumstances affect the completeness of the repair?

This report concerns only the lateral collateral ligament. The medial collateral and posterior ligaments of the knee differ from the lateral collateral ligament in that they are not discrete structures and are less accessible to surgical approach. Like Clayton and Weir, we were unable to produce comparable injuries of the knee ligaments suitable for controlled study by tearing the ligaments. For purposes of comparison, uniform injuries were needed and we could only produce these by actually cutting the ligaments.

EXPERIMENTAL STUDY

Sixty-four dogs were utilized in this part of the project. They were divided into six groups. Each group received different treatment, as indicated in Table I.

In Groups I, II, III, and IV—with twelve dogs in each group—two dogs were sacrificed at one, two, four, six, eight, and ten weeks after operation, respectively. In Group V—seven dogs—one was was sacrificed at six weeks and two at eight, ten, and twelve weeks, respectively. In Group VI—nine animals—one

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‡ The contents of this article are the personal views of the Air Force author and are not to be construed as statements of official Air Force policy.

§ The animal experiments in this project were conducted according to the rules regarding animal care as established by the University of Oklahoma Medical Center and the American Medical Association.

TABLE I

EXPERIMENTAL DATA ON SIXTY-FOUR DOGS

Group No.	Experimental Category	No. of Dogs Used
I	Transection of the lateral collateral ligament; no repair of ligament; no immobilization; gross and microscopic study	12
II	Transection of the lateral collateral ligament; no repair of ligament; leg immobilized in plaster cast; gross and microscopic study	12
III	Transection of the lateral collateral ligament; repair of ligament; leg immobilized in plaster cast; gross and microscopic study	12
IV	Transection of the lateral collateral ligament through one-half of its width; leg immobilized in plaster cast; gross and microscopic study	12
V	Transection of the lateral collateral ligament; no repair of ligament; leg immobilized in plaster cast; tests of comparative strength of the healing and normal ligaments at intervals after section	7
VI	Transection of the lateral collateral ligament; repair of ligament; leg immobilized in plaster cast; tests of comparative strength of the repaired and normal ligaments at intervals after section	9

animal was sacrificed at four weeks and two at six, eight, ten, and twelve weeks, respectively. None of the ligaments from dogs sacrificed at four weeks and only one ligament from a dog sacrificed at six weeks were studied microscopically because only the ligaments from the dogs surviving for more than six weeks after section showed appreciable evidence of solid union of the divided ligament.

In all save Group I, the legs were immobilized in plaster casts which were worn until the time of sacrifice.

As the lateral collateral ligament alone was severed, and the remaining structures on the lateral side of the knee joint were left intact, instability was not marked even at the time of operation.

At the time of sacrifice, the lateral collateral ligament was examined grossly and careful note was made of the amount of scarring and inflammation and the

FIG. 1

Gross specimen of a femur and tibia with attached normal lateral collateral ligament showing: *A*, the femur; *B*, the tibiofibular unit; and *C*, the lateral collateral ligament.

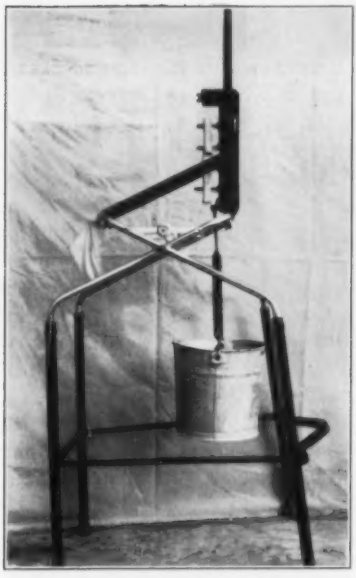

FIG. 2-A

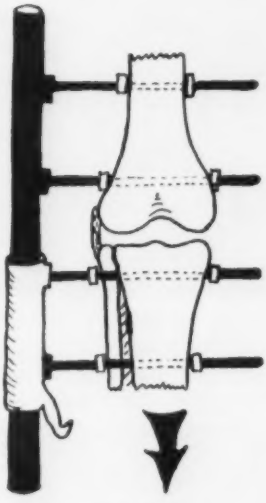

FIG. 2-B

FIG. 2-C

Fig. 2-A: Apparatus used to test the tensile strength of the lateral collateral ligament. Weights are added to the pail, which is suspended from the hook on the sliding sleeve to which the tibiofibular complex is bolted. The bones are simulated by pieces of wood.

Fig. 2-B: Diagram of specimen mounted on the apparatus to test the tensile strength of the fibular collateral ligament. The femur is fixed, bolted to the upright. The tibiofibular complex is movable, bolted to the sliding sleeve (white). Weight is suspended from the hook on the sleeve. Note that the long axes of the femoral and tibiofibular units are maintained parallel as force is applied.

Fig. 2-C: Diagram showing the rotation of the femoral and tibiofibular units, which occurs if these elements are suspended as shown. Force applied in this way caused the ligament to peel off the bone.

degree of restoration of continuity. The ligaments that were studied microscopically were resected from the femoral condyle and from the head of the fibula and fixed in 10 per cent formalin. The specimens were identified by number only to ensure unbiased study by a Board-certified pathologist (R.K.).

When the strength of the ligament was to be tested, the knee joint was dissected free of all ligaments except the lateral collateral ligament, which was left attached to four-inch segments of the distal part of the femur and upper part of the fibula and tibia (Fig. 1).

The tensile strength of the ligaments was tested to failure by the apparatus shown in Figure 2-A. The femur was fixed rigidly to the apparatus by two parallel bolts, whereas the tibiofibular unit was fixed by two similar bolts which were secured to a sliding sleeve, as shown in Figure 2-B. Loads were applied by placing metal weights in two-pound increments in the pail at approximately three-second intervals. This device was used to keep the joint surfaces parallel during testing since, when angulation was allowed to take place, the ligament tended to peel off at its osseous attachment to the fibula or femur (Fig. 2-C).

ANATOMY AND OPERATIVE PROCEDURE

The collateral and cruciate ligaments and the menisci in the knee joint of the dog are essentially the same as in man. The lateral collateral ligament attaches proximally to the lateral femoral condyle, spans the joint slightly posterior to the mid-line of the lateral aspect of the joint, and attaches directly to the head of the

fibula *. The ligament is covered superficially by a layer of loose areolar tissue which forms an incomplete sheath. At operation this sheath was observed to be very vascular; it appears to supply the main blood supply to the ligament and, therefore, should be protected. It was demonstrated by Jack that at the time of rupture, the torn ends of the ligament retract and direct contact between the ends is not restored because, when the torn ends are separated momentarily at the time of rupture, they are enveloped by the loose areolar sheath and thereby prevented from re-establishing contact with each other.

In our experiments the dogs were anesthetized with intravenous nembutal in a dosage sufficient to provide from one to one and a half hours of anesthesia. Using aseptic technique, we made a three-inch incision through the skin and fascia overlying the lateral collateral ligament which was readily palpable through the skin. When the ligament, covered by its areolar sheath, was exposed, a small hemostat was inserted beneath it and it was severed with a knife blade. The location and direction of the incision in the ligament was the same in all animals. When the ligament was repaired every effort was made to minimize the surgical trauma. The delicate instruments used in plastic surgery were employed, including very small round needles. Three sutures of 000 black silk approximated the cut ends of the tendon very nicely, even though these had separated appreciably immediately after section.

In all the animals the wounds were closed with 000 chromic catgut sutures in the fascial layer and a running suture of 34-gauge stainless-steel wire in the skin.

In the experiments in which the limbs were immobilized, a small Steinmann pin was drilled transversely through the femur three inches proximal to the joint line; a similar pin parallel to this was passed through the tibia three inches distal to the joint line. A plaster cast padded with sheet wadding was then applied to the leg, incorporating the pins in the plaster. It was found to be practically impossible to obtain rigid fixation of the dog's knee joint without the use of these pins. A well molded cast was applied with the knee in slight flexion and extended as high as possible on the thigh and distally to include part of the foot.

We had previously found that when we operated on both hind legs, the dogs were not active after operation and they sickened and refused to eat. On the contrary, when only one leg was operated on, the dogs were very active, walking on three legs as soon as the anesthetic wore off. After one or two days the dogs were walking on all four legs. Each dog was given 250 milligrams of achromycin orally each day for seven days. Each dog was checked daily for evidence of infection and signs of the cast being chewed off. In one dog the operative wound became infected but the wound healed well with antibiotic therapy. One-third of the casts had to be reinforced, but this did not significantly vary the fixation.

RESULTS

Group I: Transection of the Lateral Collateral Ligament without Immobilization or Repair (Twelve Dogs)

These knees showed some looseness of the ligament on gross inspection at four weeks (two dogs) and in one of two dogs at six weeks after operation. Edema, injection, and local swelling at the site of the incision were noted at one and two weeks after operation (four dogs). A large amount of irregular scarring was found in the region of the severed ligament in all twelve animals of this group, even at

* In the dog there is a thin, superficial lateral collateral ligament which arises from the lateral knee-joint sesamoid, located just posterior to the lateral condyle of the femur, and attaches to the head of the fibula and to the proximal part of the tibia just anterior and medial to the head of the fibula.

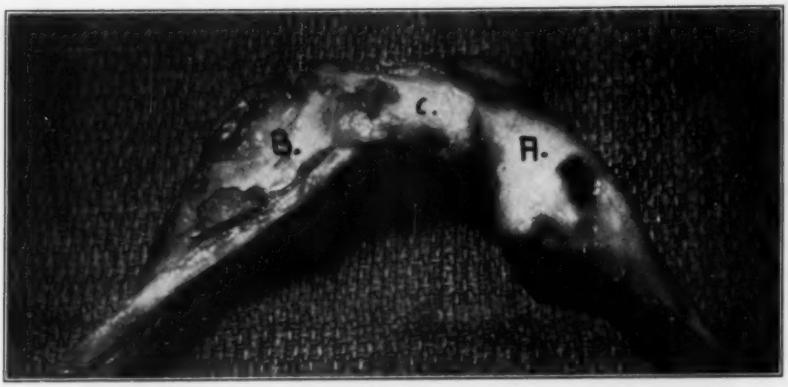

FIG. 3

Gross specimen of a dog's knee ten weeks after section of the lateral collateral ligament without subsequent repair or immobilization. Note the irregular mass of scar, *C*, on the lateral side of the knee, extending between the tibiofibular unit, *B*, and the femur, *A*. No part of the ligament can be identified.

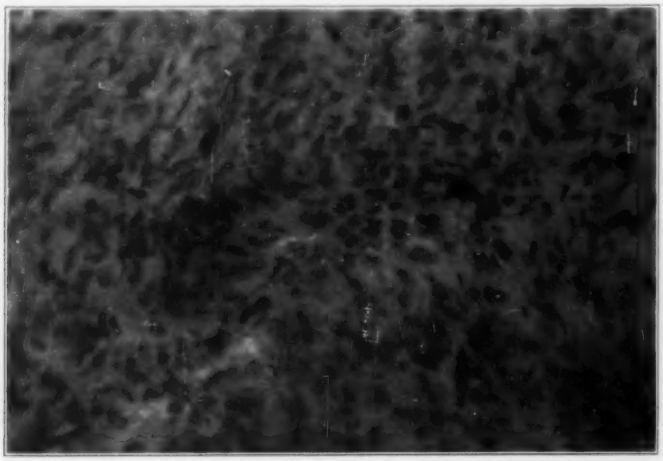

FIG. 4

Group I. Active fibroblastic proliferation and only minimum amounts of collagenization are seen at eight weeks (× 430).

ten weeks after operation (Fig. 3). This mass of scar involved the entire lateral side of the knee joint. It was impossible to identify any structure that resembled a normal ligament in any of the dogs in this group. At eight and ten weeks, the scar became more dense but otherwise did not change in appearance.

Microscopically, at one and two weeks (four animals) the ligaments showed necrosis and infiltration with inflammatory cells in the area of the severed ends. Many of the cells were polymorphonuclear leukocytes; others, immature fibroblasts and undifferentiated cells. There was a minimum amount of fibroblastic proliferation and the fibroblasts were young with swollen nuclei. From four weeks to ten weeks (eight animals) there was evidence of further fibroblastic proliferation but very little, if any, collagenization. The fibroblasts were very irregular in size and shape and showed no evidence of being oriented along lines of stress (Fig. 4). None of these scars showed any real collagenization or true ligament formation.

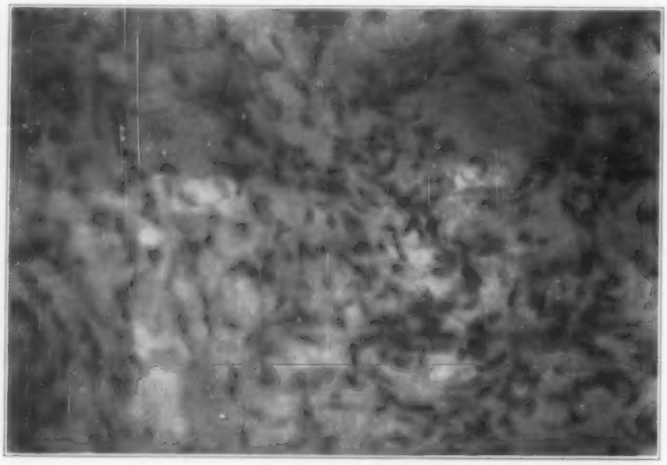

FIG. 5

Group II. Disordered arrangement of the fibroblasts at six weeks. Only scattered areas show true collagenization (× 430).

FIG. 6

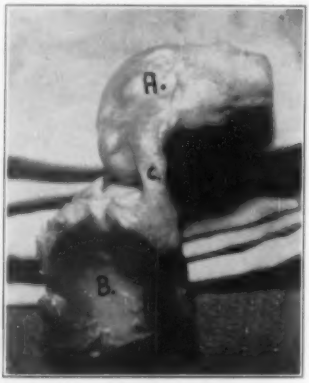

FIG. 7

Fig. 6: Gross specimens of the left and right knees six weeks after section and repair of the right fibular collateral ligament with subsequent immobilization in a plaster cast for six weeks. Compare the healed sutured ligament in *R* with the normal in *L*. Note that the sutured ligament is readily identifiable as a discrete structure with orderly disposition of the scar.

Fig. 7: Gross specimen of a knee ten weeks after section of the posterior half of the fibular collateral ligament without subsequent repair or immobilization. The ligament, *C*, extending between the tibiofibular unit, *B*, and the femur, *A*, appears to be essentially normal, with only a minimum bulge at the site of partial section.

Group II: Transection of the Lateral Collateral Ligament and Immobilization by Cast and Steinmann Pins, without Surgical Repair

Again looseness and redundancy of the ligament were noted up to four weeks (six animals). There was demonstrably less scarring than in the animals in Group I, but here also it was impossible to identify the formation of any normal ligament. The normally small collateral ligament was lost in the mass of scar that extended throughout the entire area.

Microscopically, one to four weeks after operation (four animals) these ligaments showed polymorphonuclear infiltration and necrosis. At six weeks (two animals) proliferation of large numbers of fibroblasts was observed (Fig. 5). At

eight and ten weeks (four animals) there was a significant decrease in the number of fibroblasts and an increase in the amount of collagen. The process of healing in this group was more advanced than in Group I.

Group III: Transection of the Lateral Collateral Ligament, Surgical Repair, and Immobilization by Plaster Cast and Steinmann Pins

Whereas in Group I and Group II, looseness and redundancy of the lateral ligaments were noted up to four weeks, the two ligaments in this series which were examined at one week were taut. The great amount of irregular scarring found in the unrepaired ligaments was not present in any of these ligaments at four weeks, and the lateral ligaments could be easily identified as anatomical structures in the two knees of the animals sacrificed at this time (Fig. 6).

In the microscopic sections of these ligaments, the stages of inflammation and fibroblastic proliferation were greatly shortened, compared with the liga-

FIG. 8

Group III. There is little fibroblastic activity in the healing area at six weeks. Although active collagenization is seen, the fibers are not oriented into longitudinal planes. The normal ligament is at the right edge of the illustration; the suture line is in the middle (× 430).

ments in the previous groups. At two weeks, collagenization was a very prominent feature; at four or more weeks there was heavy collagenization, although the collagen was not oriented longitudinally, as in normal tendon. The repaired area in the tendons at six, eight, and ten weeks after repair (two animals at each interval) consisted of very dense scar tissue (Fig. 8).

Group IV: Transection of the Lateral Collateral Ligament through One-Half of Its Width and Immobilization by Plaster Cast and Steinmann Pins

The tautness of the ligament at one week (two animals) was completely normal and on gross examination the ligament was readily identified (Fig. 7). In the microscopic sections at one week there was fibroblastic proliferation with only very small numbers of inflammatory cells adjacent to the normal-appearing one-half of the ligament. At four weeks, the prominent feature was collagenization (Fig. 9). At six weeks, the defect appeared to have been very nicely repaired (two animals at each time interval). However, as in Group III, longitudinal arrangement of the collagen fibers characteristic of a normal ligament was not present.

TABLE II

GROUP V (SEVEN DOGS): TENSILE STRENGTH OF LATERAL COLLATERAL LIGAMENT AT STATED INTERVALS AFTER TRANSECTION AND IMMOBILIZATION IN PLASTER CAST WITHOUT SURGICAL REPAIR

Time from Operation to Sacrifice	Dog No.	Pounds of Weight at Rupture of Ligament			Site of Rupture	
		Control (*Pounds*)	Experiment (*Pounds*)	(*Per cent of Control*)	Control Leg	Experimental Leg
12 wks.	91	24	12	50	Pulled off femur with bone flake	Pulled off femur with bone flake
	100	69	15	22	Pulled off femur with bone flake	Parted at line of transection
10 wks.	103	63	23	36	Pulled off femur with bone flake	Pulled off femur with bone flake
	94	57	17	30	Pulled off femur with bone flake	Parted at line of transection
8 wks.	93	52	37	70	Pulled off femur with fragment of bone	Parted at line of transection
	104	33	19	60	Pulled off fibula with bone flake	Parted at line of transection
6 wks.	105	91	35	38	Pulled off head of fibula at attachment	Parted at line of transection

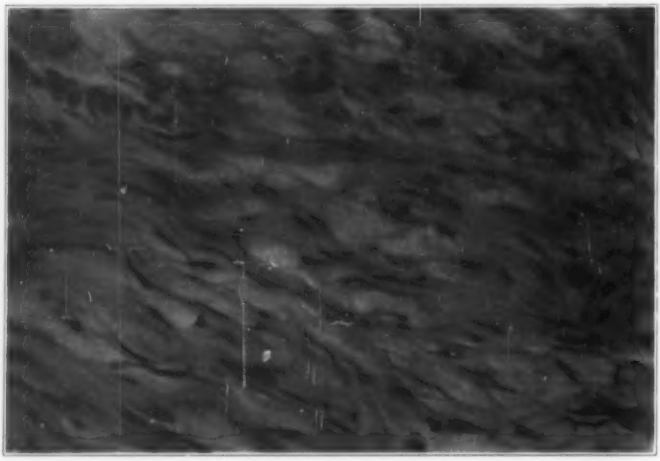

FIG. 9

Group IV. At six weeks, the important feature noted is the dense collagen tissue. This represents a higher degree of healing than is seen in Group III (× 430).

Group V: Transection of the Lateral Collateral Ligament, No Repair of Ligament, Immobilization in Plaster Cast, and Tests of Tensile Strength at Intervals after Transection

With the limb rigidly immobilized in plaster, these dogs were able to walk very well after operation. Sacrifice was carried out at designated times, and the strength of the lateral collateral ligament of the experimental leg was compared with that of the normal opposite leg, which served as a control (Table II). In both of the dogs sacrificed at ten weeks and in one of the two sacrificed at twelve weeks, the unrepaired ligament parted at the site of transection, in contrast to the control ligaments, which parted at the osseous junction (Fig. 10).

TABLE III

GROUP VI (NINE DOGS): TENSILE STRENGTH OF LATERAL COLLATERAL LIGAMENTS AT STATED INTERVALS AFTER TRANSECTION, SURGICAL REPAIR, AND IMMOBILIZATION IN PLASTER CAST

Time from Operation to Sacrifice	Dog No.	Pounds of Weight at Rupture of Ligament			Site of Rupture	
		Control (*Pounds*)	Experiment (*Pounds*)	(*Per cent of Control*)	Control Leg	Experimental Leg
12 wks.	95	31	27	87	Pulled off fibula with flake of bone	Pulled off fibula with bone flake
	96	57	17	30	Pulled off attachment at head of fibula	Pulled off femur with bone flake
10 wks.	97	89	33	37	Pulled off femur with bone flake	Pulled off head of fibula at attachment
	98	90	43	50	Pulled off femur with bone flake	Partially pulled off femoral attachment then split down ligament to tear partially through suture line
8 wks.	101	66	42	64	Pulled off attachment at head of fibula	Pulled off femur with bone flake
	102	86	32	37	Pulled off femur with bone flake	Pulled off head of fibula at attachment
6 wks.	92	112	57	51	Pulled off femur with bone flake	Pulled off femur with bone flake
	106	93	47	51	Pulled off femur with bone flake	Pulled off head of fibula at attachment
4 wks.	107	57	23	40	Pulled off head of fibula at attachment	Parted in middle at suture line

In this group of animals the severed ligament parted at much less weight than did the control ligament. Also, the experimental ligament was stronger at eight weeks than it was at ten or twelve weeks (Table II). We have not attached particular significance to this apparent loss of strength in view of the small number of animals studied. However, it does seem significant that all except one of the ligaments in this group parted at the suture line, rather than at the osseous junction. We presume that in the dog in which rupture occurred at the osseous junction, the ligament ends actually were well approximated, even without surgical repair. This certainly happens in man, which accounts for the excellent results that are observed in some patients who have not had surgical repair. In these cases we presume that the ruptured ends of the ligament spontaneously became closely approximated. We believe that it is the approximation of the tendon ends and not the stability afforded by the suture that is the important factor.

Group VI: Transection of the Lateral Collateral Ligament, Repair of Ligament, Immobilization in Plaster Cast, and Tests of Tensile Strength at Intervals after Repair

As in Group V, these dogs walked on the immobilized experimental limb until the time of sacrifice. Tensile strength of the collateral ligament of the normal leg was compared with that of the same ligament in the experimental leg (Table

FIG. 10

Result of test of tensile strength of a sectioned and unsutured fibular collateral ligament ten weeks after section with subsequent immobilization in a plaster cast for six weeks. Note that the tensile test has caused rupture at the site of original section, *C.C.* The grossly irregular scar is apparent. The hole in the femur, *A*, was made for one of the bolts on the testing apparatus. The tibiofibular unit is marked *B*.

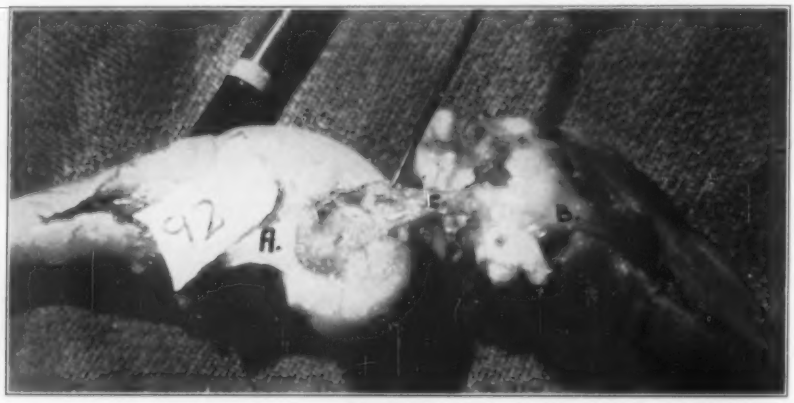

FIG. 11

Result of test of tensile strength of a sectioned and repaired fibular collateral ligament six weeks after section with subsequent immobilization in a plaster cast for six weeks. Note that the ligament, *C*, is intact and that it has avulsed a small piece of bone (metal pointer) from the femur, *A*. The attachment of the ligament to the tibiofibular unit, *B*, is intact.

III). At four weeks (one animal) the repaired ligament parted at the suture line. Thereafter, all the ligaments (eight animals) parted at the osseous attachment in a fashion similar to that observed in the control limbs (Fig. 11). In one dog (No. 98) there was also partial rupture at the suture line. As in Group V, the overall tensile strength of the ligament and its osseous attachment was substantially less in the immobilized limb than in the control limb, presumably because of disuse atrophy of the bone.

We think that the significant finding in this group of dogs was that with only one partial exception, the repaired area in the ligament was stronger than its

attachment to bone. In Dog 96, the repaired ligament at twelve weeks parted at its osseous junction with a load of only seventeen pounds, or 30 per cent of the load, at failure of the control ligament. This obviously was not a test of the strength of the repair but of the bone attachment of the ligament in a leg which had been immobilized in plaster for over twelve weeks, with resultant atrophy of the bone. In contrast to this, the experimental ligament in the other dog immobilized for twelve weeks gave way at the osseous attachment to the fibula at a load equivalent to 87 per cent of the load that caused rupture at the same point in the control ligament. In the two animals immobilized for ten weeks, the experimental ligament in Dog 98 was the one exception. This ligament split longitudinally; one-half pulling off the bone, the other half rupturing through the repair. This was believed to indicate a weak area in the repair, possibly the result of poor surgical approximation. With this one exception, from six weeks on, the repaired area was consistently stronger than the attachment of the ligament to the bone (eight animals). We did not attempt to devise an apparatus to grasp the two ends of the ligament and test its strength directly. Since the ligament was hardly large enough to ensure uniform gripping by the apparatus, it was our belief that pulling on the bone itself would be more satisfactory.

Further experiments are under way in which the animals will be allowed to run and use their legs for a while after removal of the plaster cast in order to eliminate the factor of disuse atrophy and possibly to allow a more accurate test of the comparative strength of the repaired and control ligaments.

DISCUSSION

Miltner, Hu, and Fang showed that after a mild ligament sprain in which some fibers are torn but the ligament remains functionally intact, healing follows a definite pattern. In experiments on the knee ligaments of rabbits, they found that during the first week inflammatory cells predominate; during the latter part of the first week and part of the second week, there is a gradually developing predominance of fibroblasts. This stage persists during the second and third weeks, after which collagen fibers appear and increase during the fourth and fifth weeks as the fibroblasts decrease. By the sixth week after a mild sprain, the ligament is apparently completely healed. After complete tear of a ligament, Miltner and associates showed that the process of repair was much slower. Each step was prolonged to the point that complete healing was delayed up to eight to ten weeks. It could be surmised from this that complete healing in an unrepaired ligament which was completely ruptured or avulsed from the bone would be delayed for at least ten weeks and perhaps longer.

Jack, in his work on the collateral ligament of the knee in cats, showed that healing was good if the ligament ends were in close approximation. However, if a gap remained after rupture, healing between the ends of the ligament was by diffuse, poorly organized scar tissue with very little tensile strength, with the result that the involved joint was grossly unstable.

In their studies of the healing of knee ligaments in dogs, Clayton and Weir came to conclusions similar to our own.

Our experiments have shown that the character of the scar, the speed of healing, and the strength of the healing ligament vary quite consistently according to the type of treatment given. The outstanding finding was that close approximation of the torn ligament improves the chances for complete repair.

SUMMARY AND CONCLUSION

The experiment was undertaken in response to the three questions previously

posed. We believe that these questions have been satisfactorily if not completely answered:

1. When the ends of a ruptured ligament are in approximation, healing occurs by an orderly process: first, by necrosis and cellular infiltration, then by fibroblastic invasion, and finally, by collagenization. If the ligament ends are not in close approximation, this orderly process does not occur and healing is by diffuse extensive scar formation. As time passes, the scar at the site of rupture becomes more orderly and its structure begins to resemble that of a normal ligament. Up to ten weeks, however, this scar had not become normal ligament even under the most favorable circumstances. Possibly, normal ligament would have developed if the process had been followed longer.

2. The most favorable circumstance for repair is end-to-end direct apposition of ligament fibers. This minimizes scarring, accelerates repair, hastens collagenization, and produces the most normal-appearing healed ligament.

3. Tests of the tensile strength of the divided lateral collateral ligament in our dogs suggest that after six or more weeks of immobilization, the strength of the attachment of the ligament to bone is diminished, presumably as the result of the atrophy of disuse. It would appear that during the first few weeks after such immobilization, care should be taken to prevent damage to this weakened area. This will need further confirmatory work.

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Observations in Wringer Injuries

An Experimental Study *

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This is a study of the response in the tissues of an extremity of an immature rat to the trauma delivered by a hand-operated wringer of a washing machine. Of particular interest are the changes that occur within striated muscle. By correlating the clinical behavior of the experimental animals with the gross and microscopic pathological lesions found, a hypothesis will be presented to explain the pathogenesis of the wringer-injury syndrome.

REVIEW OF THE LITERATURE

A review of the available literature failed to reveal any studies of the progressive changes that occur in striated muscle after an injury of the type produced by a washing-machine wringer. Many references have been made to the response of striated muscle to injury inflicted by venous obstruction [1,3,4,5,6,7,19,23] or arterial insufficiency [2,4,11,20,21,22,23]. From these studies the concept has evolved that capillary paralysis explains the findings observed after an inciting injury which has caused venostasis. Harman [15,18] emphasized that stasis within the capillary, venule, and arteriolar beds is the common factor which produces the pathological process seen and explains the functional recovery that follows certain types of ischemia. The factors modifying muscle repair have not been extensively studied. Regeneration of striated muscle fibers after crushing and vascular trauma was reported by Clark and associates [8,9,10]. New fibers were observed to be formed as distinct continuations of outgrowths from injured fibers. Growth was oriented in part by a proliferation of fibroblasts into the areas cleared of cellular debris by phagocytosis and in part by the preserved sacrolemmal sheaths. Partial confirmation of the main histological conclusions of the concept of muscle regeneration was furnished by Horn and Sevitt. In their study they described the growth of new contractile substance from each end of the damaged muscle fibers.

EXPERIMENTAL METHOD

Two groups of eighteen pairs of immature rats of the Wistar strain, weighing sixty to eighty grams, were anesthetized with ether and then subjected to a crushing injury in a hand-operated washing-machine wringer. Both hind limbs, one at a time, were introduced as far as the hip joint. The rollers were kept rotating continually during the full time limit of the injury, and were reversed to remove the extremity. The pressure between the rollers was calculated to be fifteen pounds per square inch, as determined by a mercury manometer. Only the extremities without lacerations or fractures were studied. One group of animals was injured for sixty seconds; a second group for 300 seconds. The duration of the injury was varied by the speed of rotation of the rollers. When the limb had passed as far as possible through the rollers, the direction of rotation was reversed. Rotation was not continued while the limb was stationary between the rollers. The rats were

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 22, 1960.

well hydrated before being injured. During the first twenty-four hours after injury, an estimate was made of the amount of water ingested by each rat. Injured animals were isolated in separate cages in an animal house where the temperature did not exceed 76 degrees Fahrenheit.

Prior to injury a measurement of the thigh circumference was made and recorded on each animal by an umbilical tape. After injury the circumference was measured at hourly intervals. The point at which the circumference of the injured limb reached twice the preinjury circumference was arbitrarily designated as the point of maximum swelling.

A second point of reference was the time when injured rats could no longer run in a rat wheel. After injury the rat was placed within the wheel half-hourly until this point was reached. This was recorded as the time of loss of functional capacity and was determined in fifty-one animals.

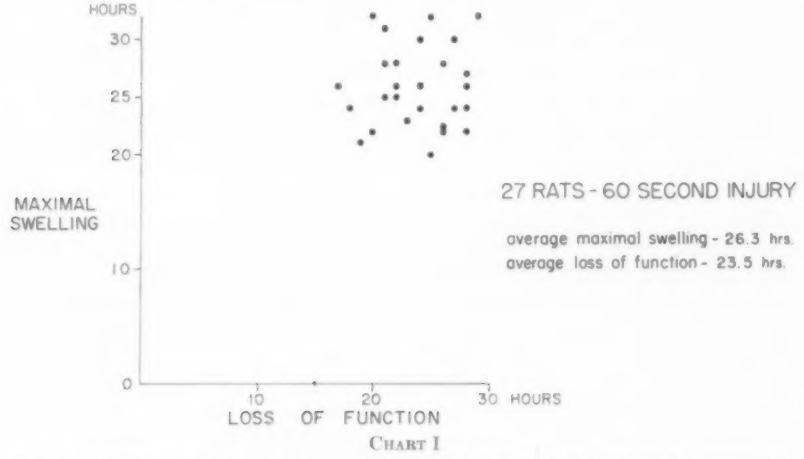

CHART I

Relationship of functional loss and maximum swelling in animals injured for sixty seconds.

The animals were sacrificed at the time of injury and at various intervals thereafter extending through twenty days. Observations were made of the gross changes before fixation of the extremities in 10 per cent formalin. The histological changes were studied in sections cut in the long axis of the limb in some animals and in cross sections in others. The tissues were stained with hematoxylin and eosin, Mallory's trichrome, and phosphotungstic acid.

PATHOPHYSIOLOGICAL-ANATOMICAL RESULTS

The results of these experiments were tabulated in terms of the physiological response of the injured limbs and the gross and microscopic pathological anatomy.

There were significant differences between the results in the animals injured for sixty seconds and the results in the animals injured for the longer period. The point of maximum swelling in the less-injured group was reached 19.8 to thirty-two hours after injury (average, 26.3 hours), whereas in the more severely injured animals this point was reached ten to twenty-three hours after injury (average, 17.4 hours). No explanation was apparent for the wide individual variation in the point of maximum swelling since the injuries in each group were produced in a uniform fashion. No correlation could be made between the point of maximum swelling and the histological changes observed.

The time that functional capacity was lost in the two groups of animals roughly paralleled the time of maximum swelling, but within each group the results—both functional capacity and swelling—varied rather widely. The average time of loss of functional capacity in the sixty-second group was 23.4 hours, whereas in the 300-second group it was reduced to 7.6 hours (Charts I and II). It should be noted, however, that after the more severe injuries functional loss appeared earlier than the arbitrarily selected point of maximum swelling. This suggests that in the more severe injuries to striated muscle, functional capacity of the injured muscle is lost before maximum edema is reached.

During the first twenty-four hours after injury, the animals were observed to require an increased intake of water. Although no quantitative tabulation of water intake was made, some animals were seen to use as much as 360 milliliters in the first twenty-four hours as contrasted to an average consumption of 200 milli-

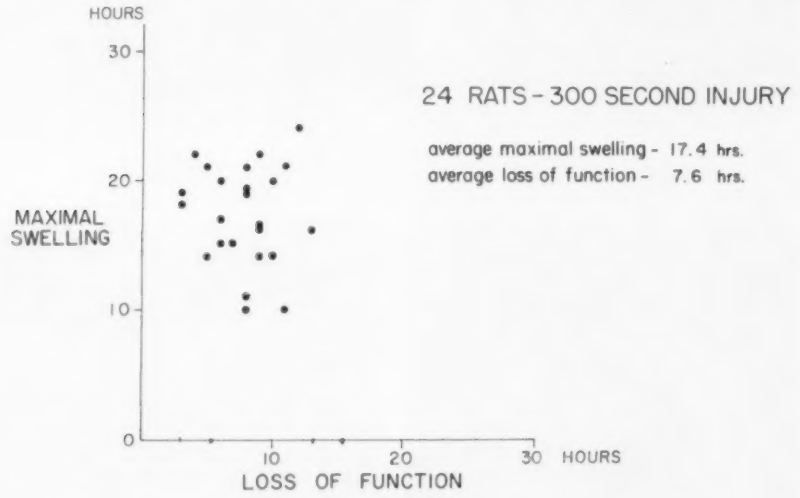

CHART II

Relationship of functional loss and maximum swelling in animals injured for 300 seconds.

liters. Three animals that had water withheld after injury did not survive this first twenty-four-hour period.

All animals which survived the initial injury, and which were not immediately sacrificed for study, demonstrated a return of function sufficient to run in the rat wheel. The exact time of this functional return was not noted.

The gross pathological changes in the muscles injured for sixty seconds and in those injured for 300 seconds were remarkably alike. The earliest specimens demonstrated red, wet, swollen muscles which bulged upon cutting through fascial planes. The outstanding features were found deep and close to the bone. Three to four days after injury the muscle was observed to demonstrate a profound softening near the bone, as contrasted to a more normal consistency of the muscle just under the skin. By the sixth day, discrete areas of tissue, gray in appearance and close to the periosteum, were demonstrable. Patchy areas of muscle replacement by scar tissue appeared throughout the specimens examined twenty days after injury.

The histological findings in each group were about the same. It may be said that the response of this striated muscle to less severe and more severe injury

FIG. 1

FIG. 2

Fig. 1: There were no changes noted immediately (× 225).
Fig. 2: Within five minutes slight hemorrhage near the bone was observed (× 225).

FIG. 3

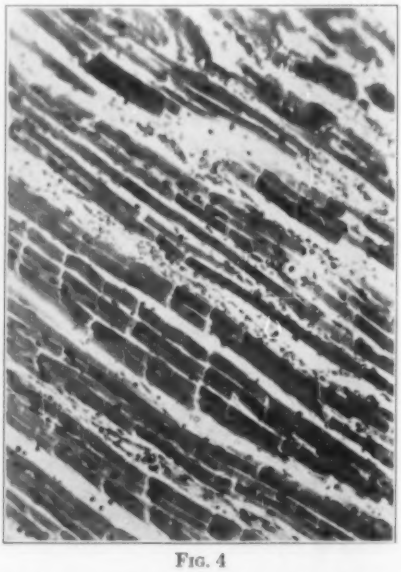

FIG. 4

Fig. 3: Sections at three and one-half hours revealed larger areas of hemorrhage near the bone and beneath the periosteum (× 150).
Fig. 4: A twelve-hour section revealed fragmentation with interfibrillar hemorrhage and edema. Necrotic fibers are pale, lack cross striations, and no longer have discernible nuclei (× 150).

seemed to follow a pattern which differed only in degree. No changes were noted immediately after injury (Fig. 1), but within five minutes slight hemorrhage near the bone was observed (Fig. 2). Sections at three and a half hours revealed larger areas of hemorrhage (Fig. 3). At twelve hours (Fig. 4) hemorrhage, edema, and fragmentation of muscle fibers appeared near the bone. Whether this fragmenta-

FIG. 5

FIG. 6

Fig. 5: A section of a sixteen-hour specimen revealed marked venous congestion (× 220).
Fig. 6: At twenty-four hours the individual muscle fibers were separated by hemorrhage and edema (× 220).

FIG. 7

FIG. 8

Figs. 7 and 8: A section at 168 hours revealed replacement fibrosis in areas of necrosis and regrowth of contractile substance into empty sarcolemmal sheaths (Fig. 7, × 215; Fig. 8, × 140).

tion was an artefact, the result in part of the histological preparation of the specimen, could not be determined. Degeneration of the muscle fibers was characterized by loss of striations, vacuolization, and granular swelling consistent with Fishback's type of degeneration [12,13]. A section at sixteen hours revealed progression of the inflammatory response with marked venous congestion (Fig. 5). At twenty-four hours, fiber degeneration, venous congestion, interfibrillar hemorrhage, and

edema were seen with a few necrotic muscle fibers (Fig. 6). Polymorphonuclear leukocytes were present in large numbers at this stage. Sections cut at 168 hours (Figs. 7 and 8) revealed replacement fibrosis in areas of necrosis and regrowth of contractile substance into empty sarcolemmal sheaths. This is consistent with regeneration of muscle fibers when the sarcolemmal sheath remains intact. Sections of muscle 382 hours after injury (Fig. 9) demonstrated patchy fibrosis with mature fibrous tissue; the remaining muscle appeared normal. It must be noted that in studying sections of these injured animals at 168 hours and later, three animals failed to demonstrate residual injury. At times one had to search several sections to find the residual patchy fibrosis of the crushing injury.

DISCUSSION

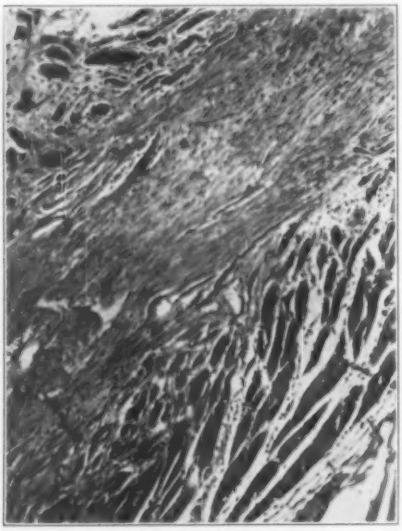

FIG. 9

At 382 hours, patchy areas of mature fibrous tissue are seen between bundles of normal striated muscle (× 180).

In these experiments there was no immediate evidence of injury either functionally or anatomically. Evidence of injury began to appear anatomically in from three to five hours and reached its maximum at about twenty-four hours. One may ask, first, what changes occurred within the muscle during the period beginning at approximately three hours after injury and reaching the maximum in approximately twenty-four hours; and, second, by what means were these changes initiated? Harman [16] stated that, "While it is irrefutable that arterial occlusion initiates the process of ischemic necrosis, it is equally certain that some other cause than persistent arterial obstruction must be sought to explain the perpetuation of the damage so inaugurated".

In Harman's studies [15,16] a profound paralysis was produced by ischemia lasting for two to three hours, after which infarction was always absent. This author concluded that the sluggish flow through the damaged muscle fiber impedes the inflow of arterial blood. Since he demonstrated that venous block was not present, the site of blockage was by deduction believed to lie in or around the venules, capillaries, and fine arterioles. In additional studies, Harman and Gwinn were able to demonstrate that after a period of ischemia followed by release of the ischemia, the necrosis of muscle progressed far beyond that produced by a comparable period of uninterrupted ischemia. In addition, necrosis of the Zenker or Fishback type was not seen in muscles until after there was cessation of ischemia. After release of the ischemia, the greatest increase in numbers of necrotic muscle fibers occurred during the first three hours.

The histological changes observed in the present experiment consisted of dilated vessels filled with blood, increased numbers of white cells, and edema. We wish to postulate, therefore, that the functional and anatomical changes in muscle fibers produced by the wringer injury are caused by edema, capillary stasis, and obstruction to arterial inflow. When these changes are severe, death of muscle

fibers results. Further substantiation of this postulate is the fibroblastic proliferation observed in the areas of muscle necrosis, a finding never present in unrelieved arterial ischemia.

We also wish to present the hypothesis (Chart III) that the tissue most seriously damaged in a wringer injury is striated muscle. This injury to muscle produces interfibrillary and intrafibrillary edema and venous and lymphatic engorgement. These changes interfere with the circulation within the muscle fibers by blocking venous return and increasing intracapillary pressure. The increase in intracapillary pressure effectively reduces local oxygen tension and alters nutrient and electrolyte exchange to a degree that muscle necrosis may ensue. Fibrous

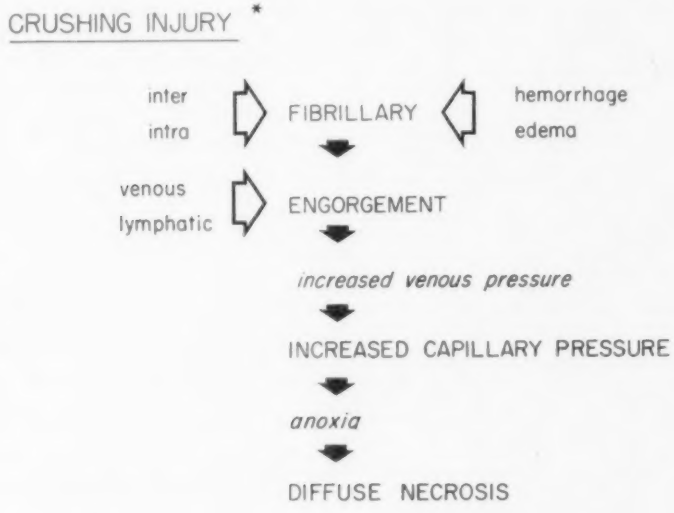

CHART III

A concept of ischemic necrosis. (Adapted from The Recovery of Skeletal Muscle Fibers from Acute Ischemia as Determined by Histological and Chemical Methods. By J. W. Harman and R. P. Gwinn. Am. J. Pathol., **25**: 741–755, 1949.)

replacement of damaged muscle fibers occurs after injury. Muscle regeneration after injury of this type has not been substantiated in this study.

The clinical effectiveness of adequate compression dressings in controlling the edema that may follow a wringer injury has been widely observed. No counterpart of this clinical observation was attempted in this experimental study. We wish to suggest, however, that compression dressings are effective treatment in wringer injuries because: (1) they reduce hemorrhage and edema mechanically; (2) they produce an increase in tissue tension, causing an expansion of the volume of the lymphatic capillary bed; and (3) they reduce venous congestion due to an equalization of the pressures in the superficial and deep venous systems.

SUMMARY

An experimental study of the effect of a wringer injury to the hind limbs of immature rats has been presented.

The findings in this study indicate that injuries produced by wringers ex-

tending over various periods of time (for example, sixty seconds versus 300 seconds) are similar histologically and vary only in degree. The histological preparations indicate that hemorrhage, edema, venous dilatation, leukocyte infiltration, and muscle necrosis may occur and that the injury is more severe near the bone. The changes first appear in from three to five hours and reach their maximum intensity in from sixteen to twenty-four hours. During this period the animals lose their ability to perform in a rat wheel.

Necrosis of striated muscle has been observed as well as late replacement of the necrotic muscle fibers by fibrous tissue. Regeneration of muscle fibers may occur after a wringer injury although the evidence in the present material is inadequate for this conclusion to be reached.

We have postulated that the factors giving rise to increased capillary pressure produce a condition of reduced oxygenation and ionic exchange at the fiber level and that these changes may produce muscle necrosis.

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A Quantitative Study of the Vascular Beds of the Hand*

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This quantitative study of the vascularity of the hand attempts to answer three questions: (1) How large is the total vascular bed of the adult hand? (2) How is that total vascular bed distributed within the hand? (3) What are some of the major differences in the vascular bed within the primary components of the hand? To answer these questions it is necessary to determine the relative mass of the component parts of the hand, the mass of the vascular bed of those component parts, and the distribution of the various sized vessels within the parts of the hand.

TABLE I

PERCENTAGE OF WEIGHTS OF PARTS OF HAND WEIGHING 335.5 GRAMS

M-P Joint to Wrist Joint		70.5 per cent
Digits		30.0 per cent
Thumb	5.0 per cent	
Index finger	6.6 per cent	
Long finger	8.6 per cent	
Ring finger	5.9 per cent	
Little finger	3.9 per cent	

MATERIALS AND METHODS

There were available for study seventy-three cadaver hands, twenty-four hands removed surgically because of disease in the upper arm, and three hands obtained from normal persons who had suffered accidents that resulted in the severance of the forearm without trauma to the hand. The three normal hands served as controls for the hands which were suspect because of disease elsewhere in the body.

Three types of procedures were used: biopsy, dissection, and the making of casts of the total vascular bed of the hand.

The biopsies were done primarily to determine the variability in the thickness of the skin. One hundred biopsies were performed on fifty cadaver hands which had been manipulated continuously throughout the period of embalming and from which one specimen of palmar skin and one of dorsal skin were removed. From these specimens, frozen sections were prepared and, at a magnification of 50×, the thickness of the dermal bed was measured by a calibrated disc in the eyepiece of a microscope.

Dissections were carried out on twenty-three hands to determine separately the volume of the digits as contrasted with the total hand and the volume of bone, muscle, and skin (Table I and Chart I).

Casts were made of the vascular bed of twenty-seven hands made available

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Miami Beach, Florida, January 7, 1961.

after surgical amputation or because of traumatic severance of the forearm in normal persons. In every instance, the blood was washed out of the vascular bed by warmed saline solution thirty minutes to two hours after interruption of the flow of blood. The specimen was then cooled as were also the plastic, the promotor, and the catalyst. These were mixed, and the plastic (methyl methacrylate) was then injected into the vascular bed through the arteries; the injection was continued until the plastic flowed freely from the veins and until the hand had again acquired its normal contour. The injection pressure was controlled to keep it within the limits of normal blood pressure: in no instance was back pressure induced by occlusion of the veins nor was the rate of flow of plastic from the veins permitted to exceed the normal rate of blood flow from the veins of the hand. Elaborate precautions were utilized to prevent premature polymerization of the plastic, including the time of mixing of the plastic, the promotor, and the catalyst, as well as very careful control of temperature. After the completion of the injection of the plastic, the specimens were stored at approximately 34 degrees Fahrenheit for forty-eight to 105 hours.

All of the tissues, except the mineral-salt framework of the bones, were digested chemically by potassium hydroxide. Although a 10 per cent solution of potassium hydroxide was used in the initial stages of digestion, the concentration of potassium hydroxide was progressively decreased. After some of the superficial tissues had been digested, the debris was gently washed away by a stream of tap water directed along the wall of the container. Thereafter, the specimen was alternately exposed to potassium hydroxide and to washing for two to three weeks until the soft tissues were removed and only a cast of the interior of the vessels and the mineral-salt framework of the bone remained. The mineral-salt framework was then removed by alternate treatment with hydrochloric acid and gentle washing with tap water. Throughout the entire process of digestion and washing, the hand remained in a fine mesh steel-wire basket on a glass plate. In spite of great care, small fragments of the plastic cast of the vascular bed were dislodged by the washing and accumulated either in the basket or upon the glass plate beneath the specimen. Three of the specimens prepared in this way were utilized in this study. These three specimens were normal and were especially well injected; there appeared to be only a few areas in which the vascular bed had not been completely filled. These areas involved some uninjected capillaries and some veins that were not completely distended.

Each of the three specimens were carefully dissected in the following manner: With iridectomy scissors and delicate forceps, the skin was removed (Fig. 1). The part of the skin from the palmar surface of the hand was placed in one set of numbered containers and the skin from the dorsum of the hand was placed in a different set of numbered containers. The part of the vascular bed within the connective tissue was next removed—the part of the bed from the palmar surface (Fig. 2) and the portion from the dorsum being stored in separate containers. The vascular bed of the individual muscles was removed separately (Figs. 3 and 4), weighed, and stored separately. The tendons of the hand were then removed and stored separately, and the vascular bed of the nerves was removed and stored

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Fig. 1: Methyl methacrylate cast of vessels of human hand. Pieces of the dermal vascular bed have been removed to demonstrate the bed of the subcutaneous tissue (reduced about ½).
Fig. 2: The same cast after removal of the volar dermal bed.
Fig. 3: Cast of the vascular bed of the opponens pollicis muscle (about × 1.5).
Fig. 4: Cast of the vascular bed of the second lumbrical (about × 1.5).
Fig. 5: Cast of the vascular bed of the ulnar nerve (about × 2).

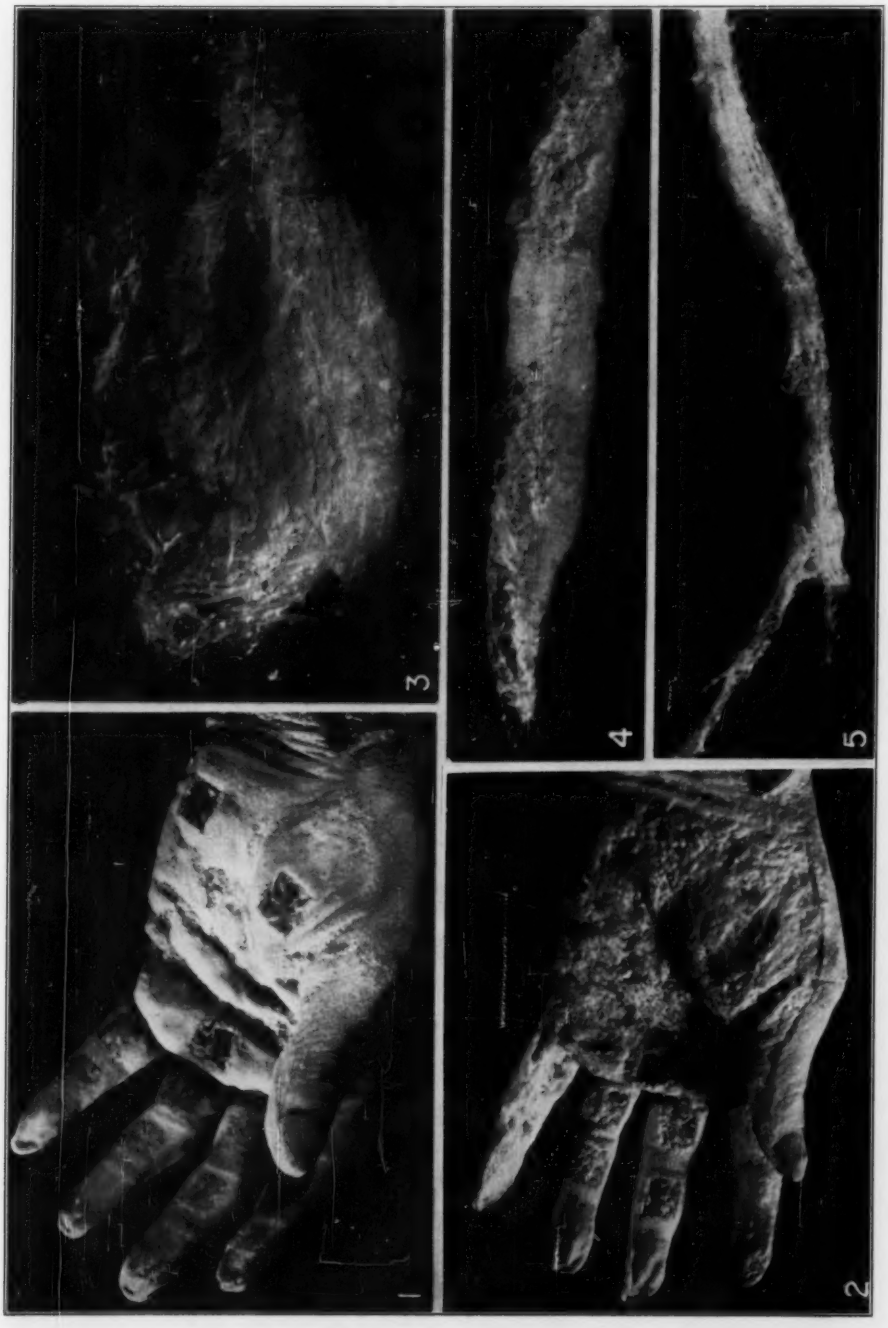
3
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TABLE II

DISTRIBUTION OF TISSUES OF A 335-GRAM HAND
(Fourteen-year-old Boy)

A. Dermis			22 per cent
B. Connective tissue			15 per cent
C. Tendons			11 per cent
1. Extensor tendons	5 per cent	= 11 per cent	
2. Flexor tendons	6 per cent		
D. Muscles			17 per cent
1. Thenar muscles	7 per cent		
2. Hypothenar muscles	3 per cent	= 17 per cent	
3. Dorsal interossei	5 per cent		
4. Volar interossei	2 per cent		
E. Bones			37 per cent
1. Carpals	9 per cent		
2. Metacarpals	16 per cent	= 37 per cent	
3. Phalanges	12 per cent		
			102 per cent *

* The 102 per cent total arose from rounding off individual values to the nearest whole number. It is the authors' feeling that the accuracy of the technique employed does not warrant the use of partial numbers.

separately (Fig. 5). Finally, the vascular bed of the individual bones was dissected and that part of the bed related to each bone was stored separately as was also the periosteum of the individual bones. The specimens were weighed on a balance which was accurate to 0.0001 gram.

The parts of the vascular bed which had been stored in individual containers and weighed separately were then teased apart with finely drawn glass rods under a dissecting microscope at a magnification of 45×. The fragments were separated into three groups: Group I was composed of fragments with a diameter of less

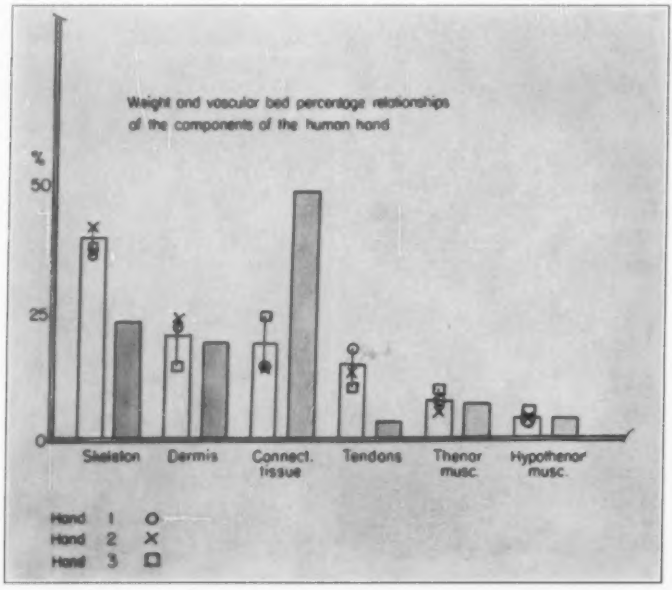

CHART I

Unshaded bars depict the percentages of the components of three human hands. The shaded bars depict the per cent of the vascular bed located within those components.

TABLE III

DISTRIBUTION OF VASCULAR BED COMPARED WITH WEIGHT OF COMPONENT PARTS OF THE HAND

	Percentage of Vascular-Bed Weight		Percentage of Hand Volume	
A. Dermis		16		22
1. Palmar	13		11	
2. Dorsal	3		11	
B. Connective Tissue		47		15
C. Tendons		2		10
D. Muscles		13		17
1. Thenar	5		7	
2. Hypothenar	2		3	
3. Volar interossei	2		2	
4. Dorsal interossei	3		4	
5. Lumbricales	1		1	
E. Bones		22		37
		100		101*

* Rounding off of values to the nearest whole numbers led to a total of 101 per cent. The authors feel that the inherent errors in the plastic injection technique do not justify the utilization of partial numbers.

than 114 micra; Group II, of fragments with a diameter between 414 and 456 micra; and Group III, of fragments with a diameter of more than 456 micra. Methyl methacrylate shrinks 15 per cent during polymerization, and, consequently, after the figures just given are corrected for shrinkage and specific gravity, the casts represent vessels 536 micra or larger, 134 to 536 micra, and 134 micra or smaller. All of the samples were then weighed on the same balance that was used for weighing during the teasing procedure. The data obtained in this way were combined appropriately to obtain the weights of the vascular bed of the components of the hand: the dermis, the connective tissues, the muscles, the tendons, the nerves, the bones, and the periosteum (Table II). For each of these components of the hand, this procedure supplied quantitative data on the amount of vascular bed composed of small vessels (to 134 micra), medium-sized vessels (134 micra to 536 micra), and large vessels (536 micra or larger) in each of the components of the hand. By relating these data to the total weight of the vascular bed, it was possible to state the percentage of the total vascular bed which lies within the dermis, the connective tissues, the muscles, the tendons, the nerves, and the bones of the hand, as well as the relative proportion of small, medium, and large vessels in each of the components of the hand.

RESULTS

In the three hands utilized in this quantitative study, the vascular bed forms about 11.8 per cent of the total volume of the hand. This vascular bed is not evenly distributed throughout the hand, and, consequently, it is necessary to consider the relative volume of the components of the hand before considering the concentration of the vascular bed within the various tissues of the hand and within the various regions of the hand. It is seen in Table I that the digits together make up 30 per cent of the hand: of the five digits, the long finger is largest, and the adjacent digits (the index and ring fingers) are significantly smaller. The remaining two marginal digits, the thumb and little finger are individually much smaller.

Nearly 70 per cent of the volume of the hand is made up of the portion of the hand between the radiocarpal joints proximally and the metacarpophalangeal joints distally. This part of the hand contains the intrinsic muscles, the tendons

TABLE IV

DISTRIBUTION BY PERCENTAGES OF SMALL, MEDIUM, AND LARGE VESSELS WITHIN THE COMPONENTS OF THE HAND

	Under 134 Microns	134 to 536 Microns	Over 536 Microns
Dermis (volar)	81	13	6
Dermis (dorsal)	75	20	5
Connective tissue (volar)	71	8	19
Connective tissue (dorsal)	51	12	38
Muscles	81	9	10
Periosteum	80	10	10
Bone	85	10	5
Nerves	67	27	6.5
Tendons	50	8	41
Average	71	13	15.5

from most of the forearm muscles, and the nerves related to the entire hand.

Table II lists the relative volumes of the five major components of the hand and Table III lists the disposition of the vascular bed within each of these five major divisions. From these tables it is seen that, although the dermis of the hand constitutes about 22 per cent of the hand, the vascular bed is not evenly concentrated within the dermis. Indeed, within the 11 per cent of the total volume of the hand which is formed by the palmar skin, there lies 13 per cent of the vascular bed of the hand. Conversely, although the dorsal dermis of the hand makes up 11 per cent of the volume of the hand, it contains only 3 per cent of the volume of vascular bed. These facts demonstrate that the ratio of vascular bed to volume of dermis on the palmar surface is about four and a third times as great as it is on the dorsal surface. This difference is partly due to the greater thickness of the skin on the palmar surface of the hand.

In our series of 100 biopsies from fifty cadaver hands, the skin on the palmar aspect had an average thickness of 1.016 millimeters, whereas that on the dorsal aspect of the hand was only 0.581 millimeter thick. Thus, the average thickness of the palmar skin was 1.8 times that of the dorsal surface. Using this figure and the difference in the volume of the vascular bed on the palmar as contrasted with the dorsal surface (palmar volume four and one-third times that of the dorsal) it can be calculated that the density of the palmar vascular bed is 2.4 times that of the dorsal bed.

The intrinsic muscles make up about 15 per cent of the volume of the hand and they contain about 13 per cent of the vascular bed of the hand. The ratio between the volume of the individual muscles and percentage of vascular bed contained in each muscle is relatively constant. This relative constancy is even more striking when compared with the difference in the concentration of the vascular bed within the skin on the palmar and dorsal aspects of the hand.

The tendons of the entire hand constitute about 10 per cent of the volume of the hand, but they contain only about 2 per cent of the vascular bed. From the foregoing, it is obvious that the concentration of vascular elements within the tendons is less than one-seventh the concentration within the palmar skin.

The bones of the hand make up almost two-fifths of the volume of the hand; and, because they are relatively vascular, they contain at least one-fifth the total vascular bed of the hand. In relative terms, the concentration of the vascular bed in the bones is about two and a half times as great as that in the tendons, but only about half as great as that in the muscles or in the palmar skin.

The general connective tissues of the hand contain nearly half of the total vascular bed, although they constitute less than one-sixth of the total volume of

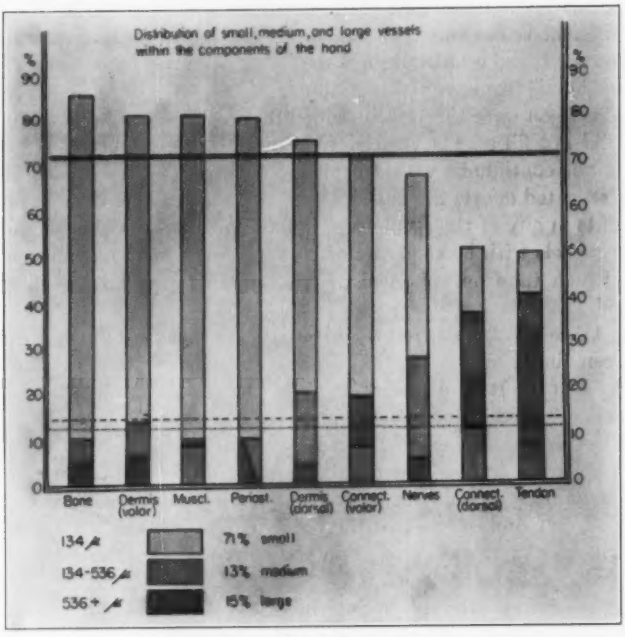

CHART II

The average contribution to the total vascular bed of the hand is indicated by three lines: the chain line at 71 per cent indicates the average for small vessels; the dotted line at 13 per cent, the average for the medium-sized vessels; and the dash line at 15 per cent, the average for the large vessels.

the hand. The general connective tissues are composed of many highly differentiated structures including the subcutaneous tissues, the deep connective tissues, the restraining bands and ligaments, as well as the septa, the walls of the spaces of the hand, and the sheaths or bursae. In all of these areas, excepting only the subcutaneous regions, the vascular bed is extremely dense and the proportion of small vessels is very high.

Within the hand, the average distribution of small vessels is 71 per cent, of medium-sized vessels 13 per cent, and of large vessels 15 per cent (Table IV). The probability that vessel size is in some way related to the function of the tissues is indicated by the finding that in some tissues the vascular bed is composed predominantly of small channels—the skin (75 to 85 per cent), muscles (81 per cent), periosteum (80 per cent), and bone (85 per cent). Conversely, other tissues contain a below-average number of small vessels—the subcutaneous connective tissues (51 to 71 per cent), the nerves (67 per cent), and the tendons (50 per cent).

The proportion of the large vessels within the various tissues demonstrates an equally revealing structural difference in the vascular bed of the components of the hand. Thus, the percentage of large vessels to the tissues of the hand is in some tissues quite low, for example, in the skin (4 to 6 per cent), in muscles (10 per cent), in periosteum (10 per cent), and in bone and nerves (each 5 per cent). Conversely, in certain tissues the proportion of large vessels which constitute the vascular bed is relatively high—general connective tissue (19 to 38 per cent) and tendons (41 per cent).

DISCUSSION

Any investigation of the total vascular space of human tissue has many

limitations, but perhaps the first is the question of normality. In this study that possible criticism is answered by the fact that the quantitative studies of the vascular bed are based on three hands that were obtained by accidental traumatic severance of hands from normal individuals.

The injections were the best obtained in twenty-seven hands, but the injection mass did not fill all the vessels. We estimate the number of afferent vessels which were not continuous with a capillary network did not exceed 10 per cent. In spite of repeated efforts the authors have not been able to demonstrate arteriovenous shunts in any of the specimens. Plastic injection may cause undue distention of the vessels with leakage and often does result in the formation of masses of plastic which take on spherical or plaque-like forms after escape from the vascular bed.

In the three hands reported in this study, the leakage did not exceed 2 per cent. The remainder of the plastic cast had the form of vessels. The capillaries appeared to be of normal diameter in all of the tissues studied, and there is no evidence indicating any artificial distention of the vascular bed.

As stated previously, small fragments of the vascular casts were dislodged during the washing and settled on the bottom of the containers. Microscopic examination of these fragments revealed that they were casts of capillaries or vessels with a diameter of less than fifty micra. The mass of the debris dislodged from the specimen and recovered from the containers was approximately 4 per cent of the total volume of plastic.

This is the initial attempt to determine the total vascular bed of a part of the human body and also to determine the distribution of small, medium-sized, and large vessels within that part of the body. Because there have been no related studies on the human being, it is necessary to compare these values with those obtained in the rat by Knisely and associates. They demonstrated in terms of cubic centimeters per 100 grams that the total vascular space averaged 10.4 cubic centimeters per 100 grams in the four rats studied. In the three human hands reported here the total vascular space averaged 11.8 cubic centimeters per 100 grams of tissue. The similarity of these values in species which are so grossly dissimilar in size is impressive. However, the similarity of these values may be misleading because it is well known [2] that the blood volume is not a linear function of weight, but varies in relation to $W^{0.72}$ (W = body weight). Perhaps it is more significant that in the human being, as in the rat, the total vascular space significantly exceeds the blood volume.

The relation of the capacity of the vascular space to the mass of the adjacent tissues may be significantly dissimilar in different regions of the body. Consequently, the capacity and distribution of the vascular bed of the hand may differ from that occurring in other parts of the body. The large amount of bone and tendon in the hand might be expected to decrease the percentage of the vascular bed located in the hand. Conversely, the complexity of the vascular bed of the dermis [6] might be expected to increase the percentage of the vascular bed in the hand.

In a report on the total vascular space in the rat, Knisely and associates emphasized the fact that the small vessels (diameter of less than 150 micra) constituted 80 per cent of the total vascular bed. In the three hands of our series the small vessels formed 71 per cent of the vascular bed. However, this average of 71 per cent was composed of the vascular bed within various kinds of tissues; in some tissues, such as the dermis of the palm or the muscles or the periosteum or the bone, the small vessels constituted 80 to 85 per cent of the vascular bed. In contrast, in other tissues, such as the tendons or the dermis on the dorsum of

the hand, the small vessels constituted only 50 to 51 per cent of the total vascular bed.

In general terms it is true that the functional status of tissue is related directly to the number of small vessels which supply that tissue [4]. Berry and associates, in their studies of the changes in the vascularity of the seminal vesicles in the rat, demonstrated that the percentage of the vascular bed composed of small vessels was about 75 during normal reproductive states. However, this percentage dropped to about 30 after castration and returned to the previous level after substitutive androgen therapy. Their study must indicate that there is a positive correlation between the functional status of a tissue and the number of small vessels related to that tissue.

In a broad sense those tissues which are metabolically active receive many vessels of small caliber (150 micra or less), and those tissues which are known to have a lower metabolic rate receive fewer small vessels. Thus the connective tissues which lie between the dermis and the tendons or bones contain a smaller proportion of small vessels and a larger proportion of large vessels.

Certainly one of the variables which enters into the distribution of small, medium, and large vessels found in a given region is the distance over which blood must be transported. Perhaps the reason the connective tissues of the hand contain so many large or medium-sized vessels is related to two facts: (1) they transmit vessels from a far-distant heart and (2) they are areas of low metabolic activity and have little need for vessels directly concerned with their nutrition.

Two of the tissues which are similar in that they have low metabolic rates have nevertheless strikingly different patterns of vascularity. The nerves and the tendons are similar in that the percentage of small vessels is low in both. In the nerves, the small vessels constitute only about 67 per cent of the vascular bed and in the tendons the small vessels constitute only about 50 per cent. They are strikingly different in that the vascular bed of the nerves contains an unusually high proportion (27 per cent) of the medium-sized vessels, whereas the vascular bed of tendons is composed of an unusually high proportion (41 per cent) of large vessels. This difference may well be related to the structural limitations imposed by the movement of these structures over the adjacent portions of the vascular bed—for example, the flexor tendons of the fingers move about one and a half inches whereas the ulnar and median nerves move very little during activity of the hand. This difference in the amount of movement may explain the high percentage of medium-sized vessels which enter the nerve at many points along its course and the high percentage of large vessels which enter the tendons either through the origin of a tendon from its muscle or from the point of insertion of the tendon onto bone.

SUMMARY

This study deals with certain quantitative relationships of the human hand—namely, the percentage of the volume constituted by such of its components as dermis (22 per cent), muscle (15 per cent), tendons (10 per cent), bone (37 per cent), and connective tissue (15 per cent) and the amount of the vascular bed located in those components.

In three of the 100 hands utilized in this study the weight and indirectly the volume of a plastic cast of the vascular spaces was determined. The vascular space constituted about 11.8 per cent of the volume of the three normal hands.

By dissecting the casts of the three hands, it was determined that the vascular bed was distributed as follows: within the connective tissue 47 per cent, within the bones 22 per cent, within the dermis 16 per cent, within the muscles 13 per cent, and within the tendons 2 per cent.

The distribution of small, medium-sized, and large vessels within each of the tissues of the hand was determined by teasing the cast apart and weighing separately the fragments with diameters less than 134 micra, with diameters between 134 and 536 micra, and with diameters larger than 536 micra. In such tissues as the dermis, muscles, periosteum, or bone, 75 to 85 per cent of the vascular bed is made up of vessels with a diameter less than 135 micra; whereas in these same tissues vessels with a diameter greater than 536 micra make up 4, 10, 10, and 5 per cent, respectively, of the vascular bed. Tissues with a low metabolic rate are supplied by fewer small vessels and transmit a disproportionate number of large vessels; thus, in tissues such as the dorsal connective tissue, the nerves, and the tendons, the small vessels constitute only 51, 67, and 50 per cent of the vascular bed, whereas the vessels larger than 536 micra make up 38, 5, and 41 per cent, respectively, of the vascular bed.

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Ulnar-Nerve Palsy in Wrist Fractures

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It is the purpose of this paper to point out that closed fractures of the carpals and metacarpals may be associated with damage to the ulnar nerve and to emphasize the necessity for thorough examination of the motor and sensory function of the hand in this type of injury. With fractures of the pisiform, the hamate, the hamulus of the hamate, the triangular bone, or the base of the fourth or fifth metacarpal, the motor branch of the ulnar nerve in the palm is highly susceptible to injury.

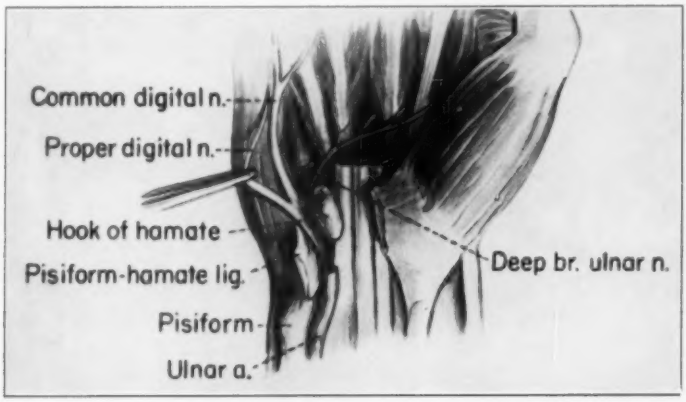

FIG. 1

Anatomy of the motor branch of the ulnar nerve in the palm.

Injury to the ulnar nerve in the wrist and palm from closed fractures has gone relatively unnoticed in the literature. In Boyes' excellent review of seventeen cases, the bulk of his patients sustained lacerations in the palm.

At the wrist, the ulnar nerve is situated within narrow confines (Figs. 1 and 2). It passes to the radial side of the pisiform and to the ulnar side of the hamate. Just beyond the pisiform, the ulnar nerve splits into superficial and deep motor branches. The superficial branch supplies sensation to the little finger and ulnar side of the ring finger and the motor branch to the palmaris brevis muscle. The deep motor branch leaves the main trunk just beyond the pisiform, curves around the ulnar side and distal margin of the hamulus, and then dives deeply into the opponens minimi as it travels toward the thumb. In contrast to the median nerve, which is the principal sensory nerve in the hand, the ulnar nerve is the chief motor nerve in the hand and innervates the hypothenar muscle group, the medial two lumbricales, all seven interossei, and the adductor pollicis, as well as the flexor pollicis brevis in 32 per cent of the 226 nerve injuries studied by Rowntree.

Six cases of ulnar-nerve injury in association with closed fractures of the wrist were observed (Table I). All these patients had considerable weakness of grip resulting from loss of function of the intrinsic muscles, particularly the very powerful adductor pollicis muscle. All had impairment of skillful motions and the

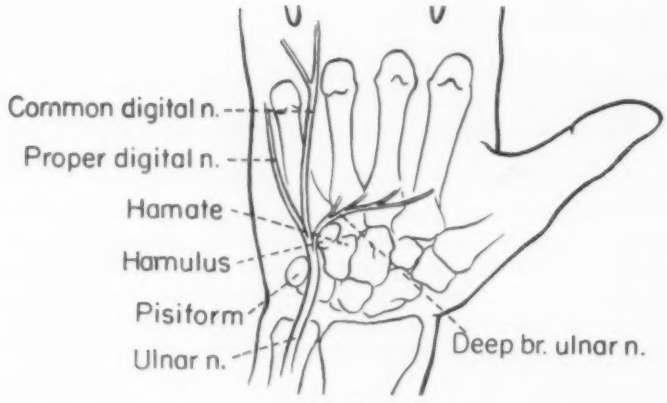

FIG. 2

Anatomy of the ulnar nerve in relation to the carpals and metacarpals.

FIG. 3

FIG. 4

FIG. 5

Fig. 3: Non-displaced fracture of the hamate.

FIG. 4: Displaced fracture of the hamate.

Fig. 5: Open reduction and internal fixation with Palmer pins. This was performed with a dorsal approach over the hamate. Reduction was easily accomplished and fixation was secured by tapping in these small Swedish nails.

delicate movements of the fingers owing to paralysis of the interossei and the two medial lumbricales. Only one patient (Case 6) showed definite loss of sensation (Fig. 9). In this instance, the fracture of the pisiform was located at a level where the ulnar nerve had not as yet divided into motor and sensory branches. Therefore, both the sensory and motor branches were susceptible to injury.

DISCUSSION

As illustrated by these six cases, closed fractures of the carpal bones and bases of the metacarpals may be associated with lesions of the ulnar nerve, particularly when the fractures are the result of blunt trauma to the dorsum of the hand (Case 5, Fig. 8) or to the volar surface of the hypothenar area (Case 1, Fig. 3). Damage to the ulnar nerve under these circumstances results from (1) severe contusion of the nerve (axonotmesis in Seddon's terminology), (2) pressure on the nerve caused by hemorrhage and edema related to the fracture, and (3) intraneural fibrosis in delayed or progressive paralysis.

TABLE I

DATA ON ULNAR-NERVE PALSY IN WRIST FRACTURES

Case	Age (*Years*)	Mechanism of Injury	Fracture	Occupation	Motor Function and Sensation	Treatment	Six-Month Follow-up
1 (P.N.)	40	Fall on left palm (dominant hand)	Body of hamate (Fig. 3)	Mechanic	The first dorsal interosseus muscle atrophied; the spread of digits decreased 1–5 cms., but power normal; adductor pollicis muscle 25 per cent of normal; negative Tinel sign; sensation intact	Immobilization in cast for three weeks; then active exercise	Grip power returning slowly; about 75 per cent of normal strength
2 (R.J.)	22	Fall on clenched right fist (dominant hand)	Body of hamate (Fig. 4)	Metal worker	The first dorsal interosseus muscle markedly atrophied; carpometacarpal joints of the ring and little fingers unstable; progressive weakness of hand; normal span; sensation intact	Open reduction of hamate; internal fixation with Palmer pins (Fig. 5)	Marked atrophy of the first dorsal interosseus muscle; adductor strong; grip powerful
3 (H.H.)	58	Left hand (non-dominant) crushed in train door	Bases of fourth and fifth metacarpals displaced (Fig. 6)	Dentist	Contraction of first dorsal interosseus muscle palpable but considerably weaker than on the right; digital span 1 cm. less and weaker *; moderate adductor weakness with atrophy; sensation intact	Immobilization in a cast for one month	Adductor pollicis weakness and atrophy; first dorsal interosseus muscle normal; grip almost normal
4 (T.S.)	19	Motorcycle accident; multiple severe injuries	Hook of the hamate; bases of the first, third, and fifth metacarpals dorsally displaced; head of the third metacarpal displaced volarly (Fig. 7)	Student	Contraction of the first dorsal interosseus muscle barely palpable; digital spread 1 cm. less and much weaker * on resistance; negative Tinel sign; sensation intact initially	Evacuation of hematoma in the thenar space and wrist because of impending ischemic necrosis	Grip is less than 50 per cent of normal; sensation of thumb is impaired owing to damage of the median nerve caused by swelling; otherwise normal
5 (A.F.)	7	Severe crushing injury caused by stone weighing 500 kgs. falling on dorsum of hypothenar region	Bases of second, third, fourth, and fifth metacarpals radially displaced (Fig. 8)	Student	Progressive clawing; atrophy of intrinsic muscles; marked weakness of grip; sensation intact	Neurolysis of deep ulnar nerve performed 10 weeks after injury because of progressive clawing	Clawing of ring finger; interosseus-muscle function appears to be returning; weak adductor pollicis
6 (J.S.)	43	Fall on outstretched right palm (dominant hand)	Pisiform (Fig. 9)	Architect	Right grip about 55 per cent as strong as non-dominant hand; weakness of first dorsal interosseus muscle; decreased digital spread (2 cms.) between little and ring fingers; weak little-finger abduction; sensory impairment of ring and little fingers	No immobilization; active motion begun immediately	Positive Tinel sign; normal first dorsal interosseus muscle; span of right hand still diminished

* Digital span as used here is a test of function of the first dorsal interosseus muscle and abductor digiti quinti. The measured span is the distance between the tips of the index and little fingers when the fingers are spread actively to the maximum. The strength of the span is tested by forcibly adducting the index and little fingers while the patient attempts to maintain them spread apart.

FIG. 6

FIG. 7

Fig. 6: Fractures of the bases of the fourth and fifth metacarpals.
Fig. 7: Fractures of the hook of the hamate and the first, third, and fifth metacarpals.

FIG. 8

FIG. 9

Fig. 8: Severely displaced fractures of the second, third, fourth, and fifth metacarpals. Note the direction of the line of force as evidenced by the displacement of the fractures.
Fig. 9: Fracture of the pisiform.

These injuries can often be treated by closed reduction of the fractures and immobilization in plaster (Case 1) or else immobilization may not be necessary (Case 6). It is important, however, to assess the function of the ulnar nerve at the outset and then follow the progress of recovery. If there is a large hematoma in the pathway of the nerve, especially in its narrow channel between the pisiform and the hamulus, the hematoma should be evacuated (Case 4). If this is done early, it may forestall ischemic necrosis of the nerve. If prompt recovery of nerve function does not occur after reduction and immobilization of the fracture, the nerve should be explored in six to eight weeks. At this procedure any tight ligaments, aponeuroses, and tendon expansions in the region of the nerve should be incised. If intraneural fibrosis exists, neurolysis should also be performed. When repair of the nerve or excision of a neuroma is indicated, the motor branch may be immo-

bilized proximally and distally and transplanted laterally into the carpal tunnel to gain additional length, as suggested by Boyes.

Unfortunately, it was not possible to follow all of these patients for more than six months; evaluation of the end result is therefore not possible. However, the patients showed a definite trend toward recovery at the end of six months. At the end of one year Case 4 showed complete recovery of his ulnar nerve while Case 3 still complained of a weak grip when using dental instruments.

SUMMARY

Six cases of closed fractures of the hand with involvement of the motor branch of the ulnar nerve at the wrist are presented. The pathway of the ulnar nerve with reference to the carpal bones and metacarpals is delineated. An outline of the procedure of treatment is proposed.

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Congenital Skeletal Limb Deficiencies

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Until the present time, child amputees have been classified as having either non-congenital or congenital amputations. Within the group of congenital amputations, both the so-called true amputation (limb-bud arrest) and the gross limb abnormality are encountered. In the fields of embryology and teratology, limb deficiencies are described with a terminology in which the terms themselves are descriptive as are the implications of these terms. Writers in the field of orthopaedic surgery have failed to adopt a relatively consistent and accurate nomenclature—one which is clear and concise, as compared with the common vague phrase *congenital amputation of the* . . . .

The classification to be presented has been evolved in an endeavor to standardize nomenclature. It does not cover *reduplication* of limbs.

In the past fifteen years, a growing interest in the care of the child amputee has been manifested by the increasing number of amputee clinics that devote their efforts exclusively to the child. These centers have progressively increased the number of patients cared for with single or multiple limb deficiencies or abnormalities. Many of these conditions are bizarre and present problems in prosthetic prescription that cannot be solved by standard prostheses.

Since World War II, the science of prosthetics has advanced phenomenally. Stumps at all levels of amputation can be fitted successfully because of the many mechanical components now available to the prosthetist. Congenital anomalies, however, are a challenge to the orthopaedic surgeon and the prosthetist in that they may be entirely unsuitable for standard prostheses because of gross variations in limb contour, substandard muscle power, and underlying skeletal deficiencies.

The various abnormalities present a frustrating problem to the surgeon who attempts to categorize them, for example, the so-called lobster-claw deformity has no less than ten different synonyms: ectrodactylism, adactyly, oligodactyly, perodactyly, monodactyly, hypodactyly, pincers, claw, crayfish-claw, and crab-claw. All these terms are used to describe partial adactylia.

The term *congenital amputation* is sometimes still used for malformation of a limb formerly thought to be the result of constriction by an amniotic band. However, "most malformations are unaccompanied by amniotic adhesions; and even when these are present, they seldom provide a plausible explanation"[18]. Intra-uterine amputations in the late months of pregnancy occur and have been documented.

The relevant literature relating to anomalies has been cited in a previous publication [13]. Certain more recent works are given in the present list of references.

The early development of the limbs has been investigated in detail in the human embryo during the past fifteen years [14,15,16]. The upper and lower limbs appear first as small buds of tissue on the lateral body wall at four postovulatory weeks [14]. These buds grow and differentiate rapidly within the ensuing three weeks, and the various regions of the limbs develop in proximodistal sequence. The arm and forearm, for example, appear before the hand, and the thigh and leg before the foot.

The skeletal elements of the limbs are found first as condensations of mesenchyme within the limb buds. These condensations soon chondrify in a definite order and ossification follows. Initial bone formation is found in the clavicle at five postovulatory weeks, in the humerus, radius, ulna, distal phalanges of the hand, femur, and tibia at seven postovulatory weeks, and in the scapula and fibula at seven weeks.

Endochondral ossification in the shaft of a bone occurs generally from one to five weeks after initial bone-collar formation has taken place. By seven weeks, all the skeletal elements of the limbs (with the exception of the clavicle, which has a different mode of development) are present individually as cartilaginous models, some of which have collars of bone in their shafts. The precise time of appearance of the individual mesenchymal condensation, the area of chondrification, and the site of initial ossification in each of the skeletal elements of the limbs have been calculated and tabulated [15,16]. By seven weeks, the joints are also well advanced and the larger synovial articulations, such as the shoulder and the hip, have begun to show cavitation. By this time, the skeleton is, in general, a replica in miniature of that of postnatal life.

It is clear that anomalies in which the number of skeletal elements is increased (for example, polydactylia and ulnar dimelia) must arise during the first seven weeks of intra-uterine life. At first sight it may seem that, due to failure of a skeletal element to persist in development, a decrease in the number of skeletal parts (for example, radial hemimelia) may arise after, as well as during, this seven-week period. Both descriptive and experimental embryological investigations, however, suggest that the various types of hemimelia arise at a very early embryonic phase.

It is to be noted that the word *postovulatory* refers to the length of time after the last ovulation, that is, the particular ovulation which resulted in the subsequently fertilized oocyte. The first seven postovulatory weeks are known as the embryonic period and the remainder of intra-uterine life as the fetal period. The distinction between an embryo and a fetus is based on the shift of emphasis in development in general from differentiation to growth. Because this distinction is too general to be of practical use, it is necessary to have available an arbitrary indicator. The level of development in the humerus is a convenient gauge of development. The onset of marrow formation in the humerus occurs when the human organism is about thirty millimeters, crown-to-rump length, at seven postovulatory weeks.

Seven descriptive terms are employed in the classification of the anomalies under discussion: *amelia*, *hemimelia*, *phocomelia*, *acheiria*, *apodia*, *adactylia*, and *aphalangia*. The first three terms are derived from the Greek *melos*, a limb: amelia means absence of a limb, and hemimelia means absence of a large part (*hemi*, a half) of a limb. Phocomelia, based on the Greek *phoke*, a seal, refers to a flipper-like limb, that is, a hand or foot which is attached more or less directly to the trunk. Acheiria and apodia are from the Greek *cheir*, a hand, and *pous*, *podos*, a foot. (These roots are found in such familiar words as chiropody and chirurgia; the latter is the Latin form from which the word *surgery*, literally meaning handwork, is derived.) Hence, acheiria and apodia mean absence of a hand and of a foot, respectively. Adactylia means absence of a digit (Greek *daktylos*, a digit) and is here reserved for those cases in which there is absence of the associated metacarpal or metatarsal as well as of the digit. Aphalangia naturally means absence of one or more phalanges.

Hemimelia may be complete (when the entire distal half of a limb is absent) or partial (when the greater portion of the distal half is absent). A third category

TABLE I

CLASSIFICATION OF CONGENITAL SKELETAL LIMB DEFICIENCIES *

TERMINAL (T)

TRANSVERSE (–)

1. *Amelia* (absence of limb)
2. *Hemimelia* (absence of forearm and hand or leg and foot)
3. *Partial hemimelia* (part of forearm or leg is present)
4. *Acheiria or apodia* (absence of hand or foot)
5. *Complete adactylia* (absence of all 5 digits and their metacarpals or metatarsals)
6. *Complete aphalangia* (absence of one or more phalanges from all 5 digits)

LONGITUDINAL (/)

1. *Complete paraxial hemimelia* (complete absence of one of the forearm or leg elements and of the corresponding portion of the hand or foot)– R, U, TI, or FI†
2. *Incomplete paraxial hemimelia* (similar to above but part of defective element is present)– r, u, ti, or fi†
3. *Partial adactylia* (absence of one to four digits and their metacarpals or metatarsals): 1, 2, 3, 4, or 5
4. *Partial aphalangia* (absence of one or more phalanges from one to four digits): 1, 2, 3, 4, or 5

INTERCALARY (I)

TRANSVERSE (–)

1. *Complete phocomelia* (hand or foot attached directly to trunk)
2. *Proximal phocomelia* (hand and forearm, or foot and leg, attached directly to trunk)
3. *Distal phocomelia* (hand or foot attached directly to arm or thigh)

LONGITUDINAL (/)

1. *Complete paraxial hemimelia* (similar to corresponding terminal defect but hand or foot is more or less complete)– R, U, TI, or FI†
2. *Incomplete paraxial hemimelia* (similar to corresponding terminal defect but hand or foot is more or less complete)– r, u, ti, or fi†
3. *Partial adactylia* (absence of all or part of a metacarpal or metatarsal): 1 or 5
4. *Partial aphalanguia* (absence of proximal or middle phalanx or both from one or more digits): 1, 2, 3, 4, or 5

* *List of symbols used:*

– transverse
/ longitudinal
: 1, 2, 3, 4, or 5 denote digital ray involved
FI or fi . . . . . fibular
I . . . . . intercalary
R or r . . . . . radial
T . . . . . terminal
TI or ti . . . . . tibial
U or u . . . . . ulnar

A line below a numeral denotes upper-limb involvement, for example, T-$\underline{2}$ represents terminal transverse hemimelia of the upper limb.

A line above a numeral denotes lower-limb involvement, for example, I-$\overline{1}$ represents intercalary transverse complete phocomelia of the lower limb.

† In capital letters when the paraxial hemimelia is complete, in small letters when the defect is incomplete.

is paraxial hemimelia. The word *paraxial*, meaning beside the axis, has been used in limb deficiencies [13] to indicate that either the preaxial of the postaxial portion of the distal half of the limb is involved. The anatomical term *preaxial*, it may be recalled, refers to the border of a limb on which either the thumb or the big toe is situated, and the term postaxial refers to the opposite border; these two terms are based on the arrangement of the limbs in the embryo at five and one-half postovulatory weeks, when the thumbs and the big toes are both on the cephalic borders of the limbs. Paraxial hemimelia may be radial or tibial (both of which are preaxial) or ulnar or fibular (both of which are postaxial). It is important to note that, by convention, the various subtypes of paraxial hemimelia are named after the absent portion. Thus, radial hemimelia refers to a deficiency of the radial portion of the forearm or of the forearm and hand.

A plan of the proposed classification is presented in Table I. The principles on which this classification is based are as follows. The defects being considered are either *terminal* (T), where there are no unaffected parts distal to, and in line with, the deficient portion, or *intercalary* (I), where the middle portion of a proximodistal series of limb components is deficient but the proximal and distal portions are present. Each of these two main groups may be either *transverse* (denoted by a hyphen), where the defect extends transversely across the entire width of the limb, or *longitudinal* (denoted by a vertical line /), where only the preaxial or postaxial portion is absent and hence the deficiency is longitudinal.

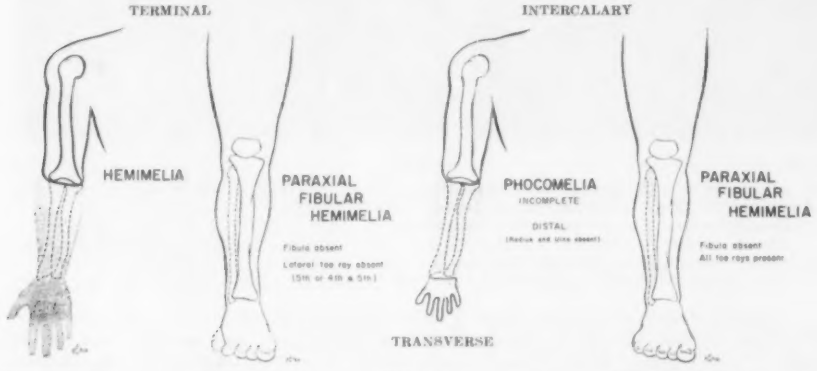


FIG 1.

Numerals (see Table I) identify subgroups within each of these four categories. A horizontal line (representing the trunk) below a symbol denotes upper-limb involvement; a line above a symbol denotes lower-limb involvement.

In paraxial hemimelia, the four subtypes (radial, ulnar, tibial, and fibular) are designated by abbreviations. When a capital letter (R, U, TI, FI) are used, the condition is complete, that is, the defective element is completely absent on roentgenographic examination. When lower-case letters (r, u, ti, fi) are used, the condition is incomplete, that is, a portion of the defective element (for example, the radius) is present.

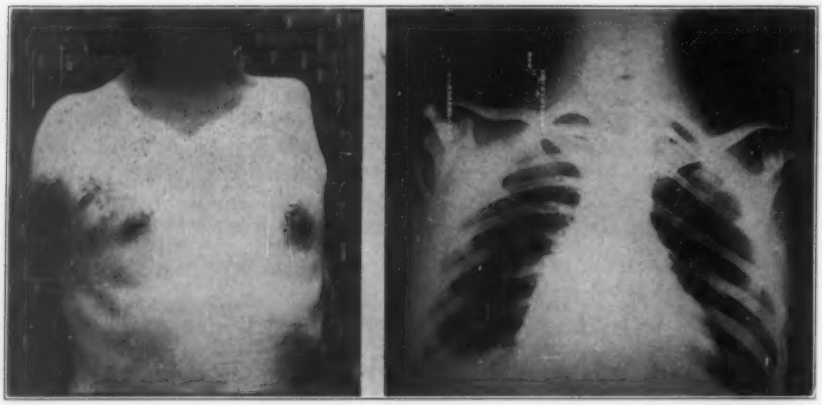
Additional numerals, placed after a colon, denote the digital ray or rays involved. The term *ray* is a convenient designation for a digit, including its metacarpal (or metatarsal) and, in some cases, the associated carpals (or tarsals) as well. The thumb, for example, is associated anatomically and developmentally with the trapezium and the navicular. In the case of most of the other digits, however, the relationship to the carpals (or tarsals) is not as clear-cut. It should be stressed that the term *ray* is used here in a purely descriptive sense, without any phylogenetic, or even ontogenetic, implications.

An endeavor has been made to use the internationally accepted *Nomina Anatomica* of 1955 throughout. It may be pointed out that the word *limb* now replaces the pedantic and inaccurately used *extremity* (the upper extremity of the body, as a momentary reflection on the anatomical position will show, is the top of the head).

Use of this classification will allow orthopaedists to designate the various deficiencies accurately. With it we can all speak the same language.

To avoid confusion with deficiencies involving the hand, it is well to keep in mind the *entire* limb: "Think of the arm—not the hand".

(Continued on page 1224)



TERMINAL TRANSVERSE AMELIA T-1

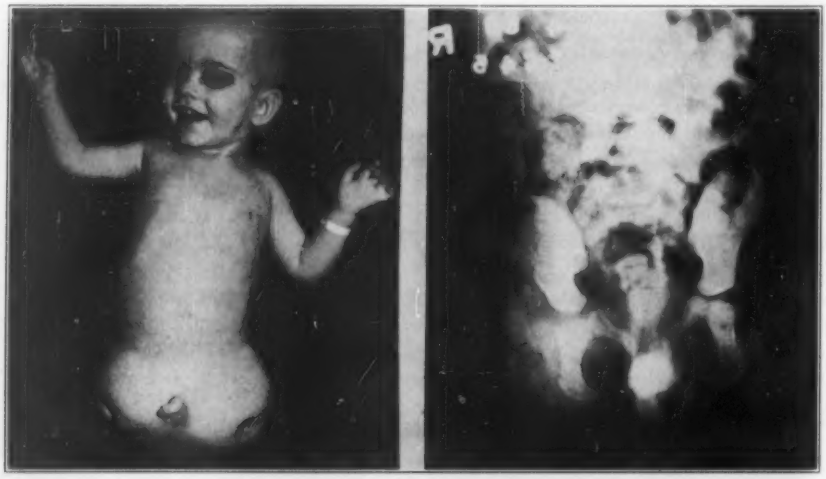
Incidence: Area Child Amputee Center: thirteen cases (nine male, four female) in 300. Seven (54 per cent) bilateral. Birch-Jensen [4] reports 1 in 270,000 births.

Genetics: sporadic abnormality, non-hereditary.

Associated defects: club foot; hare lip; cleft palate; scoliosis; complete phocomelia; distal phocomelia; lower amelia; complete paraxial hemimelia, radial.

Note: Area Child Amputee Center has one case of quadrimembral amelia.

Complete absence of the upper limb. There may be a small lobule of fat or dimple on the lateral thoracic wall. Clavicle is present. Shoulder girdle is usually very mobile. There may be accentuation of the shoulder girdle contour from excessive fat. Some cases will present a prominent acromioclavicular joint with little or no subcutaneous fat. Thoracic scoliosis often accompanies this anomaly, especially in bilateral cases [3,4,6].



TERMINAL TRANSVERSE AMELIA T-1

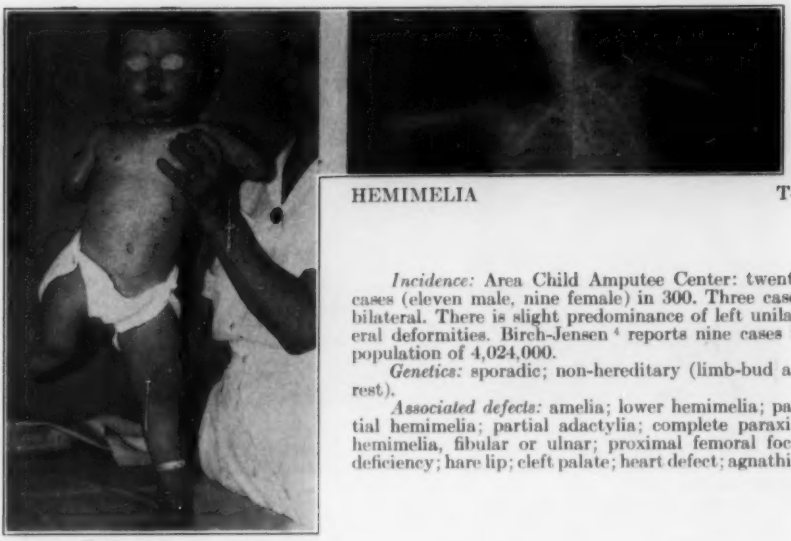
Incidence: Area Child Amputee Center: seven cases in 300. Predominantly male, 5:2. Three (43 per cent) bilateral.

Genetics: sporadic; non-hereditary.

Associated defects: proximal femoral focal deficiency; upper amelia; hemimelia; partial adactylia; complete paraxial hemimelia, ulnar.

Note: Area Child Amputee Center has one case of quadrimembral amelia.

Complete absence of the lower limb. There may be a lobule of fat or there may be a depressed area (pit) on the lateral aspect of the pelvis. The pelvic contour is wide due to accumulation of fat over hip bones [4,6].



HEMIMELIA T-2

Incidence: Area Child Amputee Center: twenty cases (eleven male, nine female) in 300. Three cases bilateral. There is slight predominance of left unilateral deformities. Birch-Jensen [4] reports nine cases in population of 4,024,000.

Genetics: sporadic; non-hereditary (limb-bud arrest).

Associated defects: amelia; lower hemimelia; partial hemimelia; partial adactylia; complete paraxial hemimelia, fibular or ulnar; proximal femoral focal deficiency; hare lip; cleft palate; heart defect; agnathia.

TERMINAL TRANSVERSE

Absence of forearm and hand—anatomically, an elbow disarticulation with the distal epiphyseal plate of the humerus present. Growth may be deficient in preadolescent age due to the altered functional demand on the humerus. Distal stump end is smooth or dimpled or it presents a a small lobule of fat in front of the limb axis [3,4,7,12].

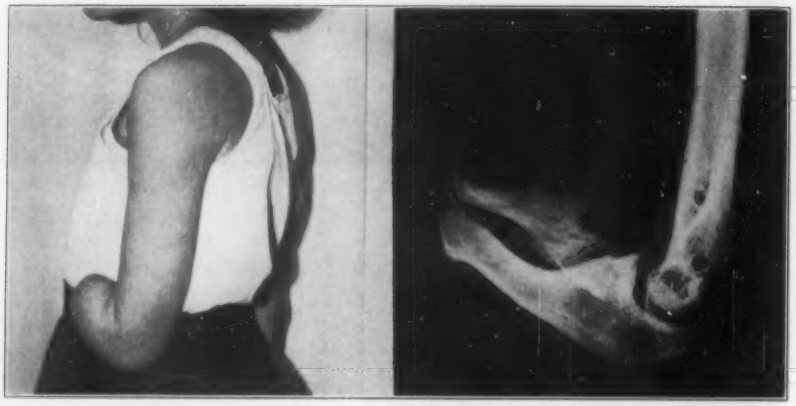
TERMINAL TRANSVERSE HEMIMELIA T-2

Incidence: Area Child Amputee Center: twelve cases (seven male, five female) in 300. Five (41 per cent) bilateral.

Genetics: sporadic.

Associated defects: upper hemimelia; partial hemimelia; acheiria or apodia; partial adactylia; complete aphalangia; amelia.

Absence of leg and foot—anatomically a knee disarticulation with the distal femoral epiphysis present. Stumps are conical and capable of end-bearing. There is usually coxa valga. Distally, there may be fat lobules behind the limb axis (popliteal area). In some cases the patella is present and voluntarily movable. The distal femoral epiphysis is apparently more "active" during growth than is the upper limb counterpart, the distal humeral epiphysis [1,3,7,12].



TERMINAL TRANSVERSE PARTIAL HEMIMELIA T-3

Incidence: Area Child Amputee Center: 112 cases in 300. Predominantly female and left-sided; only three bilateral. Birch-Jensen [4] reports 161 cases in population of 4,024,000: female, 3:2; unilateral left, 2:1.

Genetics: sporadic; non-hereditary.

Associated defects: unusual—only ten cases in 112. Syndactylism; partial adactylia; hemimelia; acheiria or apodia; partial aphalangia; club foot; heart defect; hip dysgenesis; agnathia.

Absence of a part of the distal portion of an upper limb. Forearm segment is very short; bone-stump length is less than eleven centimeters. Ulna, olecranon, and trochlea are well developed. Radius is likely to be slightly longer than ulna. Biceps tuberosity may be large and simulate radial bowing. Radial-head development is variable; it may articulate with capitulum or grow latero-proximally beyond capitulum. Skin on stump end may demonstrate small transverse ridge, depressed lobules, or ridge with five or fewer nubbins, some of which may have small finger nails. Usually a strong biceps with excellent elbow flexion power is present. Laterally the elbow is stable but hyperextensible [2,3,4,7,12,13].

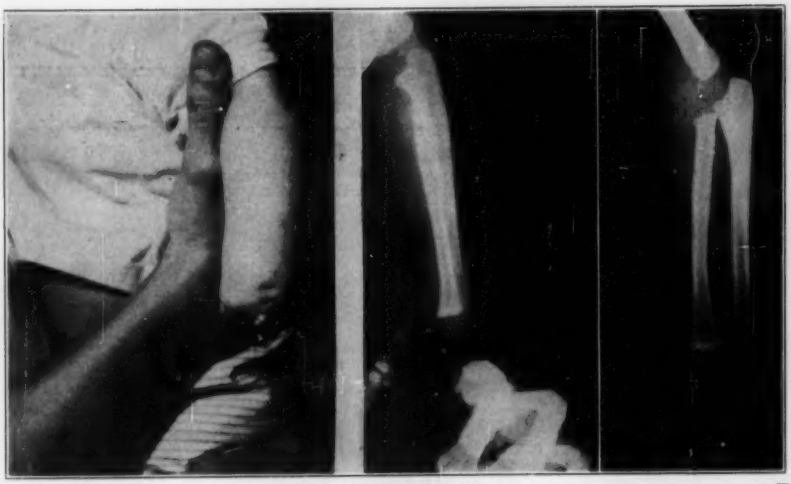
TERMINAL TRANSVERSE PARTIAL HEMIMELIA T-3

Incidence: Area Child Amputee Center: twelve cases in 300. Predominantly male, 9:3; one bilateral.

Genetics: apparently non-hereditary; sporadic.

Associated defects: hemimelia; partial aphalangia or adactylia; complete paraxial hemimelia, fibular; agnathia.

Absence of a part of the distal portion of a lower limb—anatomically a below-the-knee stump. Proximal tibial epiphysis is present with normal contour. Distal end of tibia may form a spike. There is no distal tibial epiphysis. Contour of stump may be symmetrical or deviated slightly in varus. Circular skin depressions are sometimes seen distally (ectodermal deficiency). Fibula may be absent (see T/1 FI) [2,7,13].



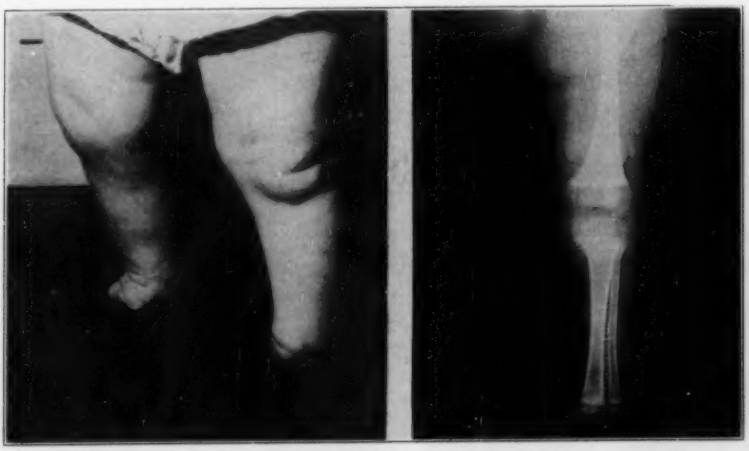
TERMINAL TRANSVERSE ACHEIRIA T-4

Incidence: Area Child Amputee Center: twenty-four (ten males, fourteen females) in 300 cases. Three bilateral. Predominantly left unilateral (62.5 per cent). Birch-Jensen [4] reports fifty-four cases in population of 4,024,000; 60 per cent left unilateral.

Genetics: great majority sporadic; possibly a recessive lesion.

Associated defects: apodia; complete aphalangia; hemimelia; partial hemimelia; radiohumeral synostosis; metatarsus varus; agnathia; hare lip; cleft palate; complete paraxial hemimelia, radial.

Absence of the hand—anatomically a wrist disarticulation with the distal epiphyses of the radius and ulna present. Pronation and supination are usually present; occasionally there is a distal radio-ulnar cartilaginous bar. Skin on stump end may demonstrate depressed transverse dimple or less distinct nubbins of skin, perhaps representing digits [2,4,12].



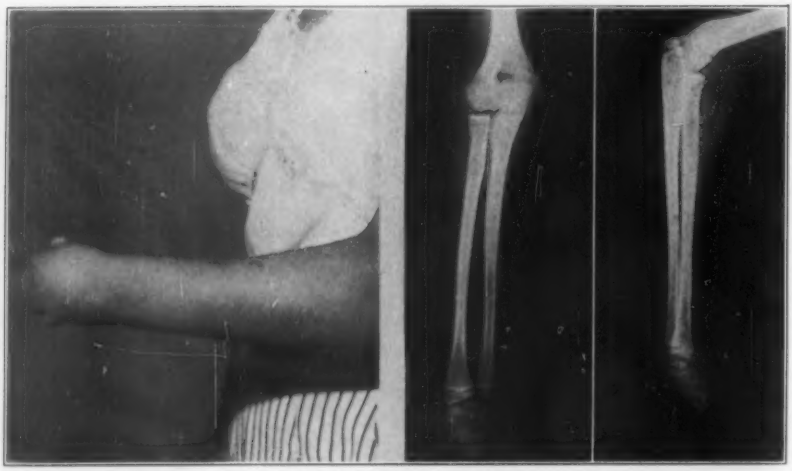
TERMINAL TRANSVERSE APODIA T-4

Incidence: Area Child Amputee Center: six cases in 300. Equal sex distribution.

Genetics: apparently sporadic; non-hereditary.

Associated defects: acheiria; partial hemimelia; hemimelia; complete adactylia; complete paraxial hemimelia; fibular; hare lip; cleft palate.

Absence of foot—anatomically an ankle disarticulation with the distal epiphyses of tibia and fibula present. Stump is fully end-bearing. Skin on plantar surface is cornified as on the normal heel. There is an anterior skin crease on the stump end. Some degree of abnormal tibial torsion may be present [2,7,14].



TERMINAL TRANSVERSE COMPLETE ADACTYLIA T-$\overline{5}$

Incidence: Area Child Amputee Center: seventeen cases in 300. Predominantly male, 12:5, no bilateral.

Genetics: great majority sporadic; possibly an inherited recessive lesion.

Associated defects: rare. Complete paraxial hemimelia, fibular.

Synonym: mitten-hand.

Absence of the digits including absence of the metacarpals and phalanges. The carpals may vary in number and configuration: they may be fused *en masse*. Flexion at the wrist is possible. The hand segment may be an oval flipper or demonstrate rudimentary representations of digits which appear as a ridge or as individual small digits [2,4,12].

TERMINAL TRANSVERSE COMPLETE ADACTYLIA T-$\overline{5}$

Incidence: Area Child Amputee Center: four cases in 300. Predominantly male, 3:1.

Genetics: possibly an inherited recessive lesion.

Associated defects: acheiria; hare lip; cleft palate.

Absence of the metatarsals and phalanges. This may be likened to the Lisfranc amputation. Tibialis anterior is present, preventing progressive equinus of the hind part of the foot. Anteriorly, there may be a raised ridge of skin on the stump end of varying size and shape, sometimes including recognizable digits. Patient has some atrophy of triceps surae and has tendency to knee hyperextension [2].

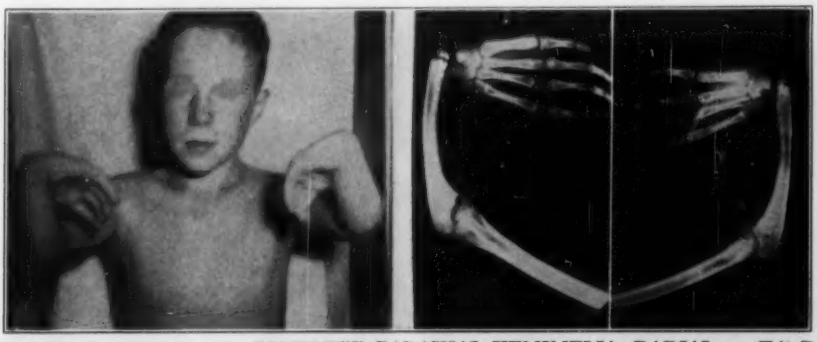
TERMINAL TRANSVERSE COMPLETE APHALANGIA T-6

Incidence: Area Child Amputee Center: eight cases in 300. Predominantly male, 5:3. Equally divided right and left unilateral; no bilateral cases. Area Child Amputee Center reports no lower-limb counterparts in this series of patients.

Genetics: probably sporadic; non-hereditary—may be recessive.

Associated defects: radio-ulnar synostosis.

Absence of the phalanges. Metacarpals are present, but they may be attenuated. Hand appears relatively broad due to deficient phalanges. Rudimentary digits represented by skin nubbins with or without rudimentary finger nails are present [3,4,7].



TERMINAL LONGITUDINAL COMPLETE PARAXIAL HEMIMELIA: RADIAL T/1 R

Incidence: Area Child Amputee Center: six cases in 300. Predominantly male, 4:2. Three (50 per cent) bilateral. Birch-Jensen [4] reports seventy-three cases in population of 4,024,000, with associated defects in 40 per cent of the cases. O'Rahilly found numerous cases reported by nine authors through 1951 [13].

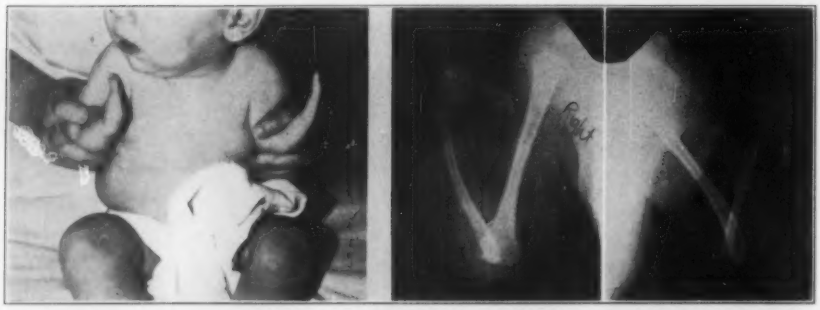
Genetics: usually sporadic; sometimes hereditary—dominant or recessive.

Associated defects: acheiria; partial aphalangia; complete paraxial hemimelia, radial or tibial; proximal femoral focal deficiency; amelia; radiohumeral synostosis.

Synonyms: radial defect; arrest of development; absence of radius; aplasia of radius; hypoplasia of radius; clubbed hand.

Note: This lesion is more prevalent than the Center's statistics reflect; this anomaly is not seen in amputee clinics, but rather in general orthopaedic clinics.

Absence of the radius and radial ray in the hand. There is a short, strong ulna, which may be bowed. The hand is radially deviated. The thumb (first ray), scaphoid, and trapezium are absent [4,6,13].



TERMINAL LONGITUDINAL COMPLETE PARAXIAL HEMIMELIA: ULNAR T/1 U

Incidence: Area Child Amputee Center: six cases in 300. Predominantly male, 4:2. One bilateral. Birch-Jensen [4] reports nineteen cases in population of 4,024,000, most often unilateral. O'Rahilly found numerous cases reported by five authors through 1932.

Genetics: apparently not inherited; may appear in families who have an accumulation of joint lesions.

Associated defects: hemimelia; partial adactylia; complete paraxial hemimelia, ulnar (Intercalary Longitudinal).

Synonyms: monodigital arm; monodigital hand; absence of the ulna.

Absence of the ulna. The radius usually articulates with the capitulum. The distal radial epiphysis is present. One digit is present which is unstable in the metacarpophalangeal joint but has flexion power. The pisiform is always present. In the majority of cases, the hamate, triquetrum, and capitate are absent. The forearm cannot be extended beyond 90 degrees of elbow flexion. Further flexion of the elbow is complete but with deficient power [2,4,12,14].

TERMINAL LONGITUDINAL COMPLETE PARAXIAL HEMIMELIA: TIBIAL T/1 TI

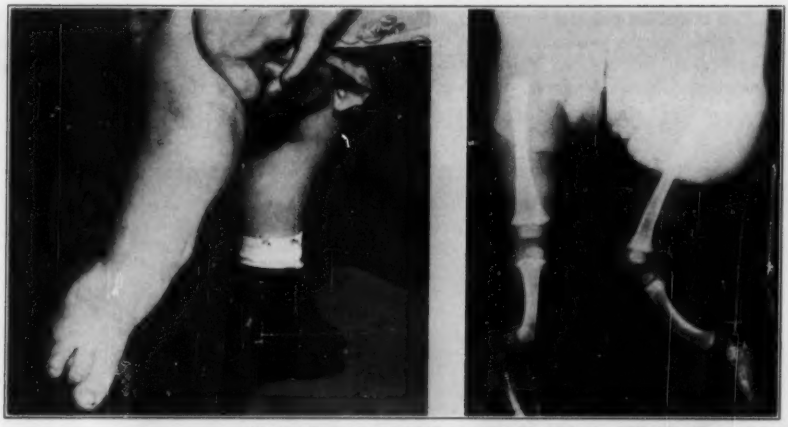
Incidence: Area Child Amputee Center: three cases (two males, one female) in 300. All bilateral.

Genetics: ? sporadic.

Associated defects: partial aphalangia.

Note: the patient illustrated has right-sided tibial hemimelia; the plantar surface of the foot is in inversion.

Complete absence of tibia. The below-the-knee segment of the limb is short. There is a flexion deformity of the knee. The foot is in varus and rotated to place the plantar surface medially. The fibula may be luxated dorsally and proximally toward the popliteal fossa. The calcaneus and talus may be fused to each other and sometimes to the navicular as well. The great toe may be absent or rudimentary. Metatarsals 1, 2, and 3 may be absent. Note that the patient illustrated has no bone elements for the first ray [1,3,12,14].



TERMINAL LONGITUDINAL COMPLETE PARAXIAL HEMIMELIA: FIBULAR T/1 FI

Incidence: Area Child Amputee Center: twenty-six cases (nineteen males, seven females) in 300. Twelve (46 per cent) right-sided unilateral. Coventry and Johnson [6] report twenty-nine cases. Thompson and associates [17] report thirty-one cases. Kruger and Talbott [11] report sixty-one complete fibular absences in forty-seven patients.

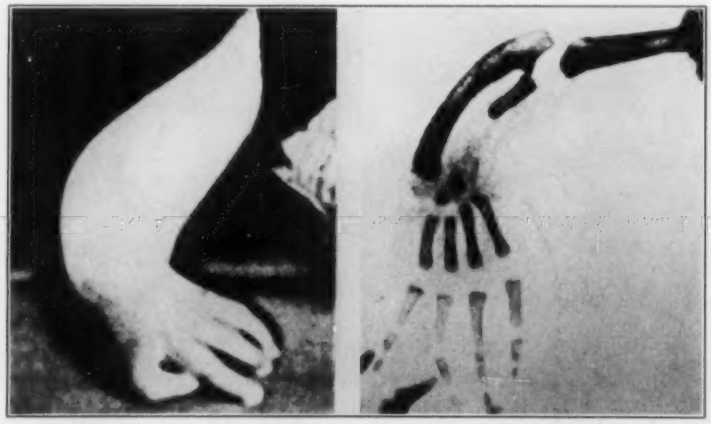
Genetics: recessive, possibly sporadic.

Associated defects: proximal femoral focal deficiency; partial adactylia; complete adactylia; hemimelia; apodia; incomplete paraxial hemimelia, radial; complete paraxial hemimelia, ulnar; partial hemimelia.

Synonyms: kyphosis of tibia; absence of fibula.

Note: proximal femoral focal deficiency, a major lesion, is often accompanied by this abnormality (Amputee Center statistics show 67 per cent).

Complete absence of fibula. The below-the-knee segment is short. Anterior bowing of tibia is present with a skin dimple at the apex of the tibial bow. The distal tibial epiphyseal plate is deficient. There is an equinovalgus deformity of the foot with one or two lateral toe rays absent. The calcaneus may be posterior and above the distal tibial epiphysis. Tarsal fusion may occur. Talus and cuboid may be absent. A fibrous band representing the fibula may be encountered at operation [1,3,5,9,11,13].



TERMINAL LONGITUDINAL INCOMPLETE PARAXIAL HEMIMELIA: RADIAL T/2 r

From Birch-Jensen [4]: *Congenital Deformities of the Upper Extremities.*

Incidence: Area Child Amputee Center reports two cases (both male, bilateral) in 300. Birch-Jensen[4] reports twenty-four cases, predominantly male, with incidence of one in 55,000.

Genetics: very small hereditary incidence; great majority sporadic.

Associated defects: many and varied. Most of Birch-Jensen's cases with accompanying defects were concentrated in a small group of patients. Sixty per cent of his patients with this deficiency had no accompanying anomalies. Aplastic anemia may be encountered with this defect.

(*Legend continued at top of page 1214*)

This resembles paraxial hemimelia, radial (complete), T/1 R, except that a portion of the radius exists, usually proximally. Note that in this deficiency the thumb (first ray) is absent. Clinically this deficiency may be similar to the complete condition (T/1 R), but roentgenographic examination differentiates them, revealing presence or absence of a part of the radius [3,4,13,14].

TERMINAL LONGITUDINAL INCOMPLETE PARAXIAL HEMIMELIA: ULNAR T/2 u

From Birch-Jensen [4]: *Congenital Deformities of the Upper Extremities.*

Incidence: Area Child Amputee Center reports no cases. Birch-Jensen [4] reports fourteen cases (eight males and six females), one per 100,000 births and one per 200,000 of population.

Genetics: insufficient statistics. Most often unilateral. Does not seem to be inherited.

Associated defects: there may be associated defects. Adactylia, partial (split-hand) or lower limb defects, or both, may accompany this deficiency.

Synonyms: hypoplasia of ulna; congenital ulnar defect.

This resembles complete paraxial hemimelia, ulnar (Terminal Longitudinal, T/1 U), except that a portion of the ulna exists. The patient illustrated has two digits, the thumb (first ray) and an unidentified digit [3,4,13,14].

TERMINAL LONGITUDINAL INCOMPLETE PARAXIAL HEMIMELIA: TIBIAL T/2 ti

(*Legend at top of page 1215*)

Incidence: no clear-cut cases reported in the literature.

This deficiency resembles complete paraxial hemimelia (Terminal Longitudinal, T/1 TI) except that a portion of the tibia is present. The foot is inverted and the great toe (first ray) is absent [1,3,13,14,19].

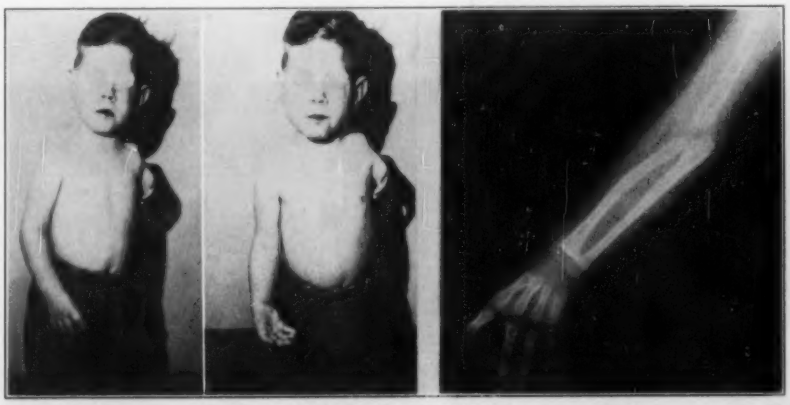
TERMINAL LONGITUDINAL INCOMPLETE PARAXIAL HEMIMELIA: FIBULAR T/2 fi

Incidence: no clear-cut cases reported in the literature.

Genetics: probably parallels paraxial hemimelia, fibular (complete, Terminal Longitudinal, T/1 FI), which is recessive and possibly sporadic.

Synonyms: incomplete ossification of fibula; kyphosis of tibia.

Clinically this resembles complete paraxial hemimelia, fibular (T/1 FI). Roentgenographic examination differentiates the two conditions, revealing a portion of the fibula to be present or absent. Note that there are four digits; the fifth is absent. If all toes were present this would be incomplete paraxial hemimelia, fibular (Intercalary Longitudinal, I/2 fi) [1,3,5,9,11,13].



TERMINAL LONGITUDINAL PARTIAL ADACTYLIA T/$\underline{3}$

Incidence: Upper Limb: Area Child Amputee Center: seventeen cases (involving divers rays) in 300. Predominantly male, 11:6. Usually unilateral. Birch-Jensen [4] reports eighty-five cases.

Lower Limb: Area Child Amputee Center: six cases (four males, two females) in 300 [3,4,13,15].

Genetics: generally sporadic; a few cases may be recessive (inherited).

Synonym: synbrachydactylism.

Associated defects: proximal femoral focal deficiency; amelia; hemimelia; complete phocomelia; distal phocomelia; complete paraxial hemimelia, fibular or ulnar; partial hemimelia; hare lip; cleft palate.

Note: patient illustrated presents T/$\underline{3}$:1. The left upper limb is intercalary transverse complete phocomelia (I-$\underline{1}$).

Absence of one to four digits in the hand or foot along with their metacarpals or metatarsals,

TERMINAL LONGITUDINAL **PARTIAL APHALANGIA** T/4

Incidence: Upper Limb: Area Child Amputee Center: ten cases (six males, four females) in 300; divers rays involved. Usually bilateral. Birch-Jensen [4] reports fifty-six cases (involving the third ray) in population of 4,024,000.

Lower Limb: Area Child Amputee Center: three cases (all female; two bilateral) in 300, involving divers rays [4,13,16].

Genetics: most cases apparently spontaneous. When inherited, condition is *dominant.*

Associated defects: proximal femoral focal deficiency; paraxial hemimelia, fibular or radial; partial or complete aphalangia; partial hemimelia; apodia: dysplastic hip.

Synonyms: ectrodactylism; adactylia; oligodactyly; perodactyly; monodactyly; hypodactyly; pincers; claw; crayfish claw; crab claw; lobster claw.

Absence of one or more phalanges from one to four digits. In the hand the rays may deviate and form a cone-shaped cleft, thus dividing the hand into two parts; there may be syndactylism of fingers on either side of cleft.

INTERCALARY TRANSVERSE **COMPLETE PHOCOMELIA** I-1

Incidence: Area Child Amputee Center: six cases in 300. Equal sex distribution. Two bilateral. Birch-Jensen [4] reports five cases (not regionally classified as to complete, proximal, or distal) in population of 4,024,000.

Genetics: insufficient statistics.

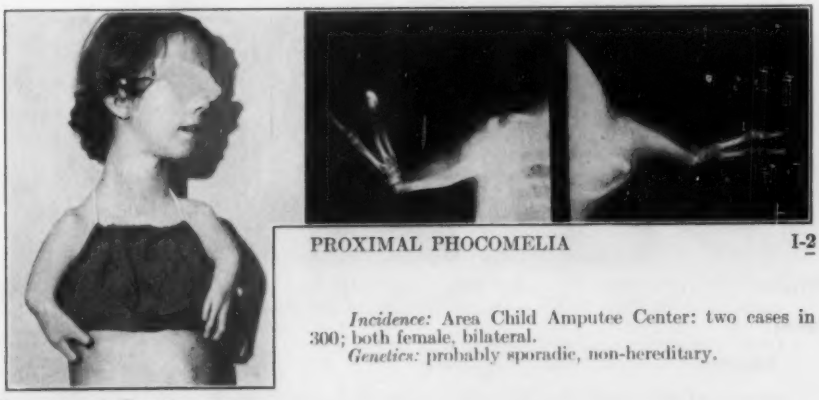
Associated defects: amelia; incomplete adactylia; distal phocomelia; arthrogryposis. Note: skeletal deficiencies usually are not symmetrical when bilateral.

Absence of the proximal portions of the upper limb. The hand is attached to the trunk and rests in the coronal plane. There may be deficient rays of the index to little finger inclusive. Digits are in flexion. Flexion power may be sufficient to be functional. Extension power of digits is very poor. Syndactylism may be present: by roentgenographic examination small, undifferentiated bone segments may be recognized [3,4,6,7,13].

INTERCALARY TRANSVERSE COMPLETE PHOCOMELIA I-1

Incidence: Area Child Amputee Center: five cases in 300. All male; one bilateral.
Genetics: insufficient statistics.
Associated defects: partial adactylia; hip dysplasia; proximal femoral focal deficiency; complete paraxial hemimelia, fibular.

Absence of the proximal portions of the lower limb. Foot is attached to trunk wall. Toe rays may be absent. Flexion of the toes is possible but not extension. Roentgenographic examination shows that tarsals may be absent or present in varying degrees. Acetabulum may be nonexistent; its roof index may measure 15 degrees [2,7,13].

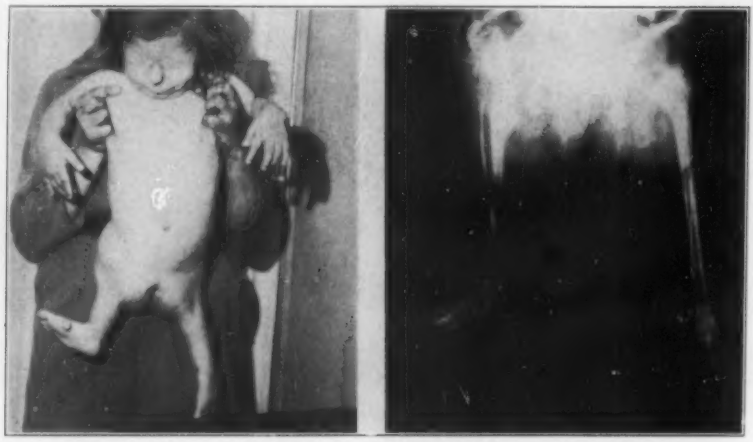


PROXIMAL PHOCOMELIA I-2

Incidence: Area Child Amputee Center: two cases in 300; both female, bilateral.
Genetics: probably sporadic, non-hereditary.

INTERCALARY TRANSVERSE

Absence of the humerus (the proximal segment of the arm). The patient illustrated demonstrates absence of the radius. Roentgenographically, the forearm here has an ulna. Shoulder girdles are atrophic. All joints are unstable. Hands flex on the arm with fair power, but are deficient in extension. Intrinsic muscle function in the fingers is deficient; they flex but lack extension. Finger rays vary in number [3,4,6,7,13].



INTERCALARY TRANSVERSE PROXIMAL PHOCOMELIA I-$\bar{2}$

Incidence: Area Child Amputee Center: two cases in 300. Both bilateral.
Genetics: probably sporadic, non-hereditary.
Associated defects: radiohumeral synostosis; cleft palate; complete paraxial hemimelia, fibular or ulnar.

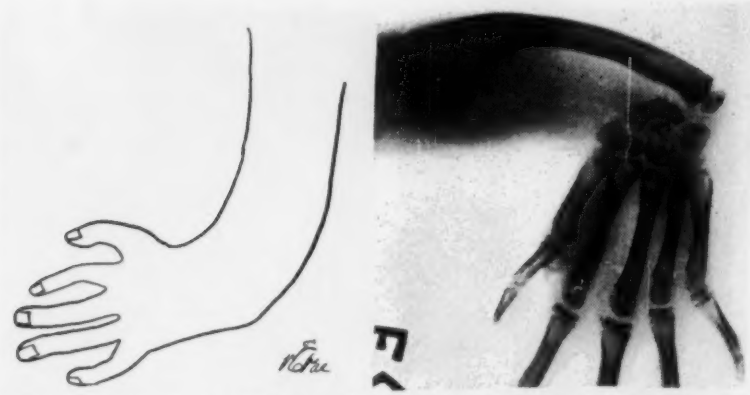
Absence of the femur. The proximal ends of the tibia and fibula rest close to the external surface of the ilium. There is no acetabulum. The junction of the tibia and ilium is very unstable and incapable of weight-bearing. Ligaments if they exist are relaxed. The leg can be rotated much like the hands of a clock [8,10,13].

INTERCALARY TRANSVERSE DISTAL PHOCOMELIA I-$\bar{3}$

Incidence: Area Child Amputee Center: ten cases in 300. Predominantly male, 7:3. Three bilateral.
Genetics: sporadic; non-hereditary—may be recessive.
Associated defects: partial adactylia; amelia.

Absence of radius and ulna. The arm is short. Finger rays vary in number. There is good flexion power of the wrist and fingers. Carpohumeral joint is quite stable. Shoulder abduction is limited. Roentgenographic examination usually reveals that the distal end of the humerus is forked. This may represent distorted condylar development.

Lower Limb Counterpart (I-$\bar{3}$):
Incidence: Area Child Amputee Center: one case, male, bilateral.
Associated defects: complete phocomelia; amelia [4,7,13].

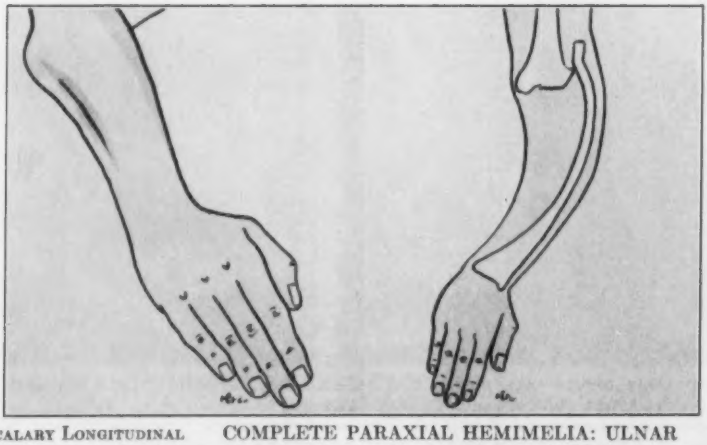


INTERCALARY LONGITUDINAL COMPLETE PARAXIAL HEMIMELIA: RADIAL I/1 R

From Birch-Jensen [4]: *Congenital Deformities of the Upper Extremities.*

Incidence: Area Child Amputee Center reports one case in 300. Female, unilateral. Birch-Jensen [4] includes this deficiency in his presentation of radial defects and aplasias.

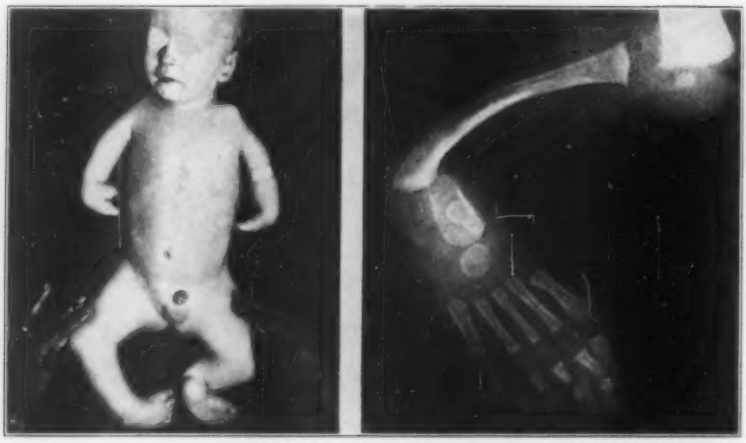
This deficiency resembles complete paraxial hemimelia, radial (Terminal Longitudinal, T/1 R), but demonstrates a complete hand with five digits [4,6,12].



INTERCALARY LONGITUDINAL COMPLETE PARAXIAL HEMIMELIA: ULNAR I/1 U

Incidence: Area Child Amputee Center: one case (male, unilateral) in 300.

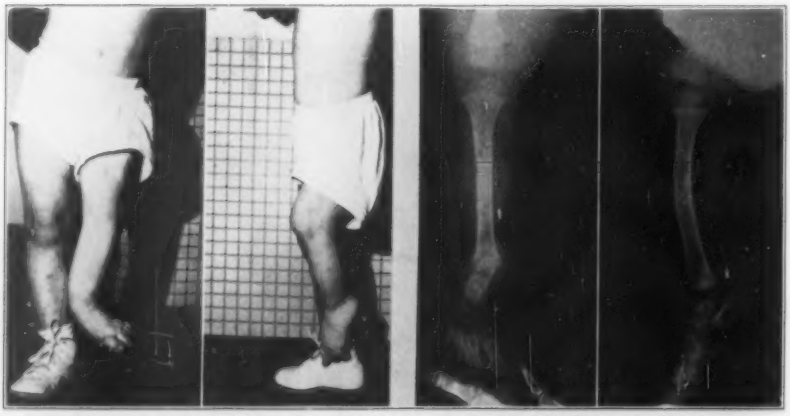
This deficiency resembles complete paraxial hemimelia, ulnar (Terminal Longitudinal, T/1 U), but the hand is complete with five digits [3,4,13,14].



INTERCALARY LONGITUDINAL COMPLETE PARAXIAL HEMIMELIA: TIBIAL I/1 TI

Incidence: Area Child Amputee Center: three cases in 300 (two males, one female; no bilateral).
Genetics: sporadic; possibly hereditary; non-recessive.
Associated defects: complete paraxial hemimelia, radial; microtia.

The tibia is absent. There are five toe rays, indicating that the foot is not involved. Otherwise this anomaly skeletally parallels complete paraxial hemimelia, tibial (Terminal Longitudinal, T/1 TI) [3,7,13].



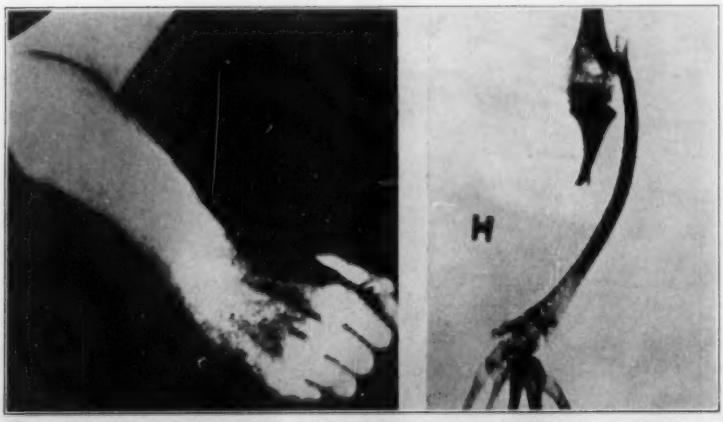
INTERCALARY LONGITUDINAL COMPLETE PARAXIAL HEMIMELIA: FIBULAR I/1 FI

Incidence: Area Child Amputee Center: ten cases in 300. One bilateral; six males, four females.
Genetics and associated defects: see Terminal Longitudinal, Complete Paraxial Hemimelia, Fibular (T/1 FI).

The fibula is absent. This deficiency differs from Terminal Longitudinal Complete Paraxial Hemimelia, Fibular (T/1 FI), in that there are five digits, indicating normal skeletal components in the foot. The foot sometimes rests in valgus [1,2,5,9,11,13].

INTERCALARY LONGITUDINAL INCOMPLETE PARAXIAL HEMIMELIA: RADIAL I/2 r
From Birch-Jensen [4]: *Congenital Deformities of the Upper Extremities.*
Incidence: Area Child Amputee Center reports no cases. Birch-Jensen [4] includes this deficiency in his presentation of radial defects.

This deficiency differs from Incomplete Paraxial Hemimelia, Radial (Terminal Longitudinal, T/2 r) in that there are five digits [3,4,13,14].

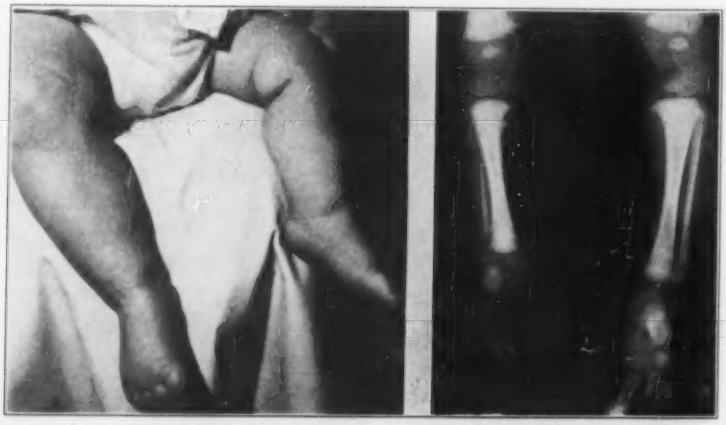


INTERCALARY LONGITUDINAL INCOMPLETE PARAXIAL HEMIMELIA: ULNAR I/2 u
From Birch-Jensen [4]: *Congenital Deformities of the Upper Extremities.*
Incidence: Area Child Amputee Center reports no cases. Birch-Jensen [4] classifies this among deficiencies with ulnar defects.

Clinically this appears to be a ventrally bowed forearm with apparent luxation of the elbow and a defect on the ulnar side of the forearm. Five digits are present. Roentgenographic examination discloses a portion of the ulna to be present (see Incomplete Paraxial Hemimelia, Ulnar; Terminal Longitudinal, T/2 u) [3,4,13,15].

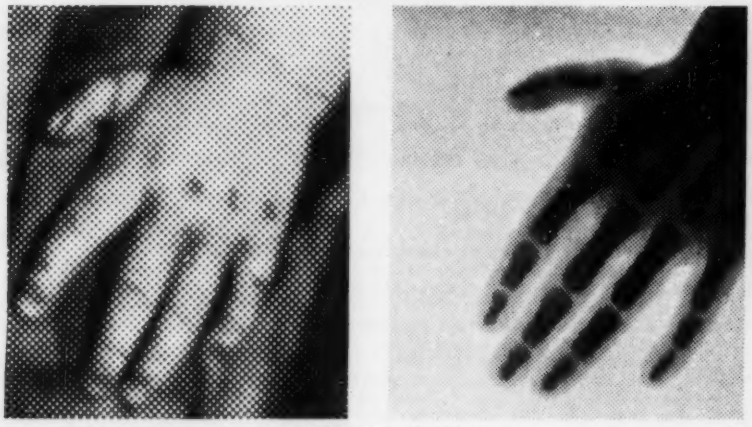
INTERCALARY LONGITUDINAL INCOMPLETE PARAXIAL HEMIMELIA: TIBIAL I/2 ti
Courtesy of Chestley L. Yelton, M.D., Lloyd Noland Hospital, Fairfield, Alabama
Incidence: Area Child Amputee Center: three cases (one male, two females) in 300.
Genetics: insufficient knowledge.
Associated defects: proximal femoral focal deficiency; complete paraxial hemimelia; radial; partial adactylia; partial aphalangia.
Synonym: delayed ossification of the tibia.

This differs from Complete Paraxial Hemimelia, Tibial, in that a portion of the tibia (usually proximal) is present, with a complete or incomplete proximal tibial epiphyseal plate. If there were fewer than five digits, this would be a terminal longitudinal defect [1,3,13,14,19].



INTERCALARY LONGITUDINAL INCOMPLETE PARAXIAL HEMIMELIA: FIBULAR I/2 fi
Incidence: Area Child Amputee Center: one case (female) in 300.

This differs from Complete Paraxial Hemimelia, Fibular (I/1 FI), in that roentgenographic examination reveals a portion of the fibula to be present, usually distally. If there were fewer than five toes, this would be a terminal longitudinal defect [1,3,5,9,11,13].



INTERCALARY LONGITUDINAL PARTIAL ADACTYLIA I/3

From Birch-Jensen[4]: *Congenital Deformities of the Upper Extremities.*

Incidence: Area Child Amputee Center reports no cases. Birch-Jensen[4] classifies this deficiency with radial defects and aplasias (nineteen cases: reported population incidence is one in 55,000).

Genetics: may be inherited and dominant, but the great majority is not inherited.

Synonym: floating thumb.

Absence of all or part of a metacarpal or metatarsal. The styloid process of the radius, the scaphoid, and the trapezium are usually either absent or small. The hand illustrated shows this deficiency in the thumb ray, the so-called floating thumb. This type of deficiency is not seen in amputee clinics [4,13].

INTERCALARY LONGITUDINAL PARTIAL APHALANGIA I/4

Incidence: Area Child Amputee Center: two cases in 300. Birch-Jensen[4] reports forty-one cases in population of 4,024,000.

Genetics: sporadic in majority of cases; when inherited it is dominant.

Synonyms: ectrodactylism; hypophalangia.

Associated defects: lower hemimelia; partial hemimelia.

Absence of the proximal phalanx or middle phalanx, or both, from one or more digits. In the hand illustrated only the little-finger ray is intercalary; note that the distal phalanx is present as is the finger nail (the ring-finger ray is T/4:4—the distal phalanx is absent) [4,13,15].

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Note: This study was done under the aegis of Carleton Dean, M.D., *Director*, Michigan Crippled Children Commission.

The authors wish to express their appreciation to Shirley Furgerson for her great help in compiling cases and statistics and to Richard Rae for his extensive photographic work.

Giant-Cell Tumor in the Metaphysis in a Child

Report of an Unusual Case

BY MARY SHERMAN, M.D., AND RICHARD FABRICIUS, M.D., NEW ORLEANS, LOUISIANA

From the Department of Orthopedic Surgery, Ochsner Clinic, New Orleans

In the last twenty years, especially in the United States, there has been a gradual, profound change in the thinking about giant-cell tumors. This conceptual revolution has been well summarized by Lichtenstein who, with Jaffe and Portis, did so much to bring it about. If one adheres to the diagnostic criteria of these authors, it is evident that giant-cell tumor is an uncommon lesion. Furthermore, it is so rare in patients younger than twenty years of age that, as Lichtenstein wrote, the odds are very much against anyone who ventures a diagnosis of giant-

Fig. 1

The initial roentgenograms show the lesion confined to the metaphysis and diaphysis of the lower portion of the left radius. The epiphyseal plate is intact; but there appears to have been some asymmetrical growth disturbance, as evidenced by loss of the normal angulation of the radiocarpal joint. The lesion has expanded the medial portion of the radius somewhat, but the cortex is still intact.

cell tumor in a child or an adolescent. It also is true that the epiphyseal location of this tumor in long bones is so characteristic that there are relatively few exceptions to this rule. If the strict diagnostic criteria of Jaffe, Lichtenstein, and Portis [3,6] are applied, most of the older literature on giant-cell tumor is automatically invalidated, particularly that related to giant-cell tumors in children or to lesions in non-epiphyseal locations. The cases that have been reported [1,2,4,5,6,7,11,13] cannot all be accepted as examples of the lesion under discussion. Most recent authors agree with the concept outlined by Jaffe,

FIG. 2

Roentgenograms made immediately after the first operation. The epiphyseal cartilage was neither seen nor disturbed when the defect was curetted.

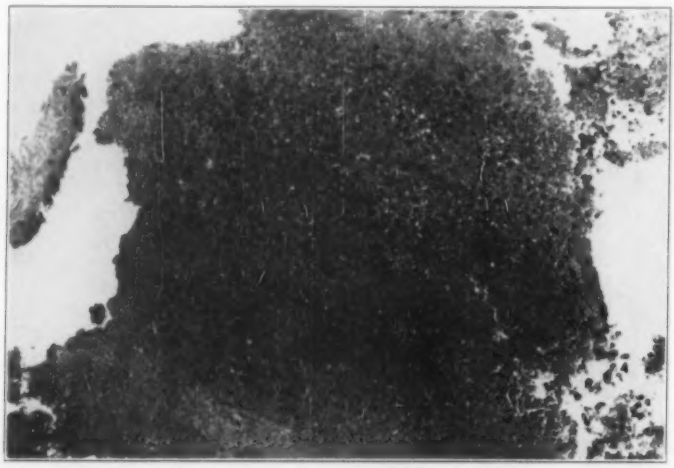

FIG. 3-A

Figs. 3-A and 3-B: Low-power (Fig. 3-A, × 20) and high-power (Fig. 3-B, × 200) photomicrographs of typical fields of the tumor. The pattern was the same everywhere. The appearance of the recurrence was identical with that of the original tumor. Note the lack of definition and general syncytal appearance that are characteristic of this lesion.

Lichtenstein, and Portis and by Lichtenstein, but there are still dissenters [4,10,12]. The case under consideration is presented because, although the microscopic appearance of the lesion is that of a classic giant-cell tumor, it violates the other clinical rules. To our knowledge there is recorded in the literature no other instance of an unequivocal giant-cell tumor proved to have arisen in the metaphysis of a long bone with its epiphyses still open.

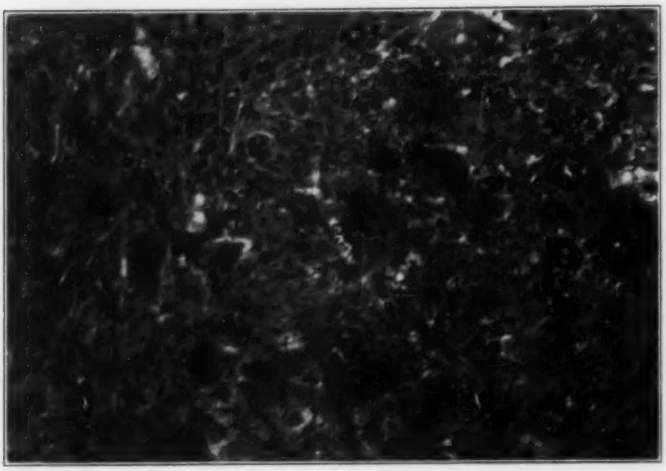

FIG. 3-B

FIG. 4

Roentgenograms made nine months after the first operation show healing of the proximal portion of the lesion in the diaphysis but further growth of the metaphyseal portion. Increased expansion of the medial cortex and penetration of the epiphyseal plate are noted. There has been additional retardation of growth of the radius with overgrowth of the ulna.

CASE REPORT

The patient was a white boy just fifteen years old who was physiologically immature and whose epiphyses were still open. He had no complaints before February 22, 1954, when in the crush of a Carnival crowd, he fell heavily, striking his left wrist against a curb so that his hand was forced into hyperextension. He went at once to Charity Hospital in New Orleans, where examination revealed an extensive destructive process in the metaphysis and diaphysis of the lower part of the left radius (Fig. 1). The lesion appeared not to involve the epiphyseal plate, and, at operation a few days later, this was found to be true. The cortex of the radius was intact, but thin and bluish. The defect was smooth-walled, single, and filled with friable grayish red tissue of the consistency of brain. This was thoroughly curetted and the cavity was packed with grafts taken from the patient's ilium (Fig. 2). Microscopic examination revealed a loose vascular tissue composed of round or oval cells with rather indistinct cytoplasm. Scattered everywhere were innumerable giant cells, the many nuclei of which were identical with those of the stromal cells.

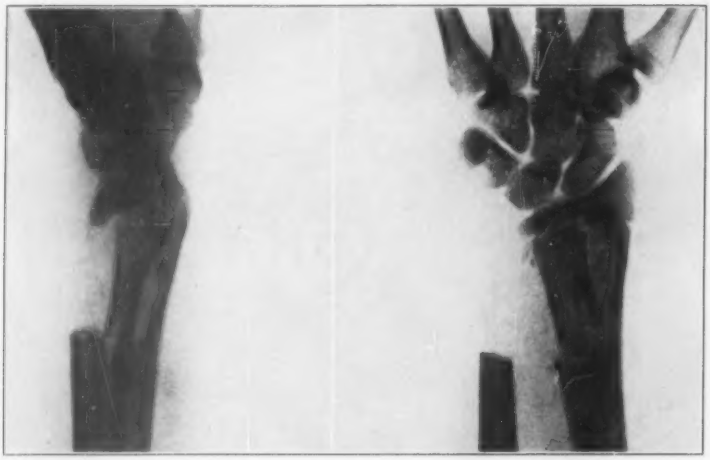

FIG. 5

Roentgenograms made after the second operation. The lower part of the ulna was resected, split in two, and fitted into the area of resection, which included the remains of the epiphyseal cartilage of the radius.

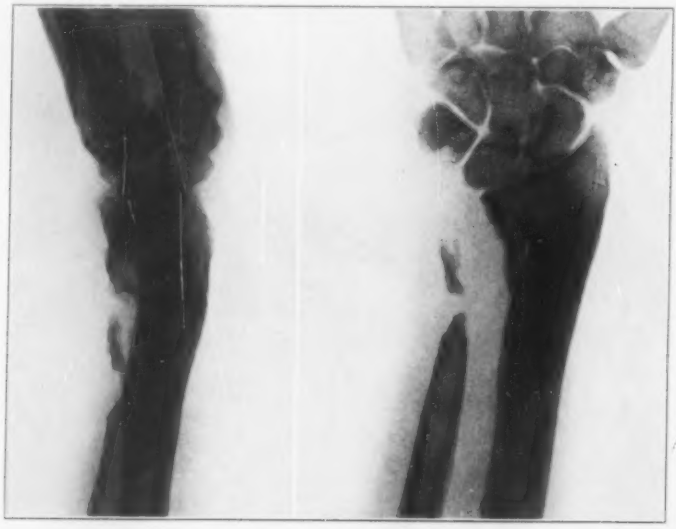

FIG. 6

Roentgenograms made seven years after the resection and ulnar graft. There is deformity of the radius but healing of the tumor. There is good painless function of the wrist despite 15 degrees limitation in extension and ulnar deviation of the hand. The patient has no complaints.

The cell boundaries of the giant cells were often indistinct and the cytoplasm frequently seemed to blend with that of the stromal cells in a sort of syncytium. Regular mitoses were seen in the stromal cells fairly often. Patches of foam cells were seen here and there, as well as small areas of delicate fibrosis. The pattern of this lesion was remarkably uniform and rather typical of what is usually called a benign giant-cell tumor (Figs. 3-A and 3-B).

The wound healed without difficulty as did the proximal portion of the bone lesion. The roentgenogram nine months after curettage, however, showed the metaphyseal portion of the radius to be expanding with beginning penetration of the epiphyseal plate (Fig. 4).

At a second operation, the lower end of the ulna was resected and used as a graft (Fig. 5).

As before, the cavity was single, smooth-walled, and filled with the same friable tissue. The defect in the epiphyseal plate was clearly visible, and plate and tumor were resected. The microscopic appearance of the tissue removed was in all respects identical to the first. Recovery was again uneventful and the bone defect filled in gradually. The roentgenogram made seven years after the second operation showed healing with moderate deformity (Fig. 6). When examined at that time the patient had good function of the wrist and no complaints; he was working without difficulty at a mechanical job.

DISCUSSION

Considering the microscopic appearance of this lesion, together with its biological behavior, the diagnosis of giant-cell tumor seems inescapable. We are thus confronted with a giant-cell tumor that originated in the metaphysis of a long bone in which the epiphyseal plate was still intact. By the time of the second surgical intervention, the tumor had penetrated, but not completely destroyed, the epiphyseal plate. It is obvious that if this boy's accident had not precipitated roentgenographic examination and if the lesion had evolved unmolested for a longer time, it would have presented initially the classic picture associated with giant-cell tumor of the lower part of the radius. It is interesting to speculate on how often this may be the case.

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Chondro-Ectodermal Dysplasia (Ellis-van Creveld Syndrome)

Report of a Case and Review of the Literature

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Chondro-ectodermal dysplasia (Ellis-van Creveld syndrome) is a form of achondroplastic dwarfism characterized by multiple malformations of the ectoderm and mesoderm, including polydactyly, ectodermal dysplasia (affecting nails and teeth), and chondrodysplasia; it may also be associated with congenital cardiac anomalies [2,6,11,22,23].

This syndrome was originally described by Ellis and van Creveld, in 1940. They reported on two personal cases and included as a third the case described by McIntosh, in 1933, as ectodermal dysplasia. In Table I are recorded the principal findings in cases of chondro-ectodermal dysplasia reported to date [2,6,11,19,22,23]. For a diagnosis of the Ellis-van Creveld syndrome to be established, a minimum of three of the four principal anomalies must be present. Accordingly, we have excluded the third case of Metrakos and Fraser, which had only two of the elements of the syndrome, and the case of Gallagher, MacGregor, and Israelski because it resembled Morquio's disease rather than chondro-ectodermal dysplasia. Although the case of Debré, Lamy, Minkowsky, and Grumbach is analyzed, it is not computed in the statistics because only two of the typical features were present even though the histopathological findings were characteristic.

Caffey described constant and inconstant features. The constant features include hypoplasia of teeth and nails; progressive shortening of the bones of the arms and legs; bilateral polydactyly, polymetacarpalia, and synmetacarpalia; hooklike bilateral fusion of the capitate and hamate bones; delayed maturation of the primary ossification centers of phalanges with accelerated maturation of the secondary epiphyseal cartilages; and characteristic deformities of the proximal end of the tibiae. The inconstant features are alopecia; joining of the upper lip and gum; congenital cardiac anomalies; dislocation of the head of the radius; delayed maturation of sesamoid bones in the hand; and pedal polydactyly, syndactyly, and polymetatarsalism.

The patient is an achondroplastic dwarf with shortening of the limbs. The skull is normal with no depression of the base of nose. The teeth are dysplastic with marked alterations in their morphological and chronological development. The trunk is of normal size and shape for the patient's age, although some patients have been described with keel-shaped or barrel-shaped chests [19]. The shortening of the limbs is acromelic in character, rather than rhizomelic, as in achondroplastic dwarfism. There is a supernumerary cubital sixth finger, the nails are fragile and fluted and rarely extend out to the end of the digit. The malformation of the proximal epiphysis of the tibia causes genu valgum.

The reported congenital cardiac anomalies include auricular and ventricular

TABLE I

Case	Series		Age	Sex	Ectodermal Dysplasia	Polydactyly	Chondrodysplasia	Congenital Cardiopathy
1	1933 McIntosh			F	+	+	+	−
2	1940 Ellis and Van Creveld	1	20 mos.	F	+	+	+	+
3		2	4 yrs. 3 mos.	M	+	+	+	+
(		3	4 yrs. 4 mos.	1932	[first case: McIntosh]			)
4	1951 Keizer and Shiler		21 yrs.	F	+	−	±	+
5	1951 Weller		2 yrs.	F	+	+	+	+
6	1951 Gatto		15 yrs. 13 mos.	F	+	+	+	+
7	1952 Debré and associates		14½ yrs.	F	+	+	+	+
8	1952 Caffey	1	3½ mos.	F	+	+	+	+
9		2	13 mos.	F	+	+	+	+
(		3	19 yrs.	F	[first case: McIntosh]			)
†(	1952 Debré and associates		N.B.	F	−	−	+	+)
10	1953 Neimann and associates		6½ mos.	M	+	+	+	+
12	1954 Midulla		11 yrs.	F	+	+	+	−
13	1954 Metrakos and Fraser	1	14 yrs.	M	+	+	±	−
13		2	5½ yrs.	M	+	+	±	−
†(		3	18 yrs.	M	+	+	−	−)
14		4	3 yrs.	F	+	+	±	−
15		5	18 yrs.	M	+	+	±	−
16	1954 MacGregor		7 yrs.	M	+	+	+	−
17	1955 Chauss		7 mos.	F	+	+	+	+
18	1955 Weiss and Crosset		6 mos.	M	+	+	+	+
19	1956 Turner		N.B.		+	+	+	+
20	1956 Akoun and Bagard		N.B.	F	+	+	+	+
21	1956 Weyers	1	12 days	F	+	+	+	+
†(		2	1 yr.	F	−	+	+	−)
22	1957 Uehlinger		N.B.	M	+	+	+	+
23	1958 Lucentini and Massenti		29 yrs.	M	+	+	+	+
24	1958 Smith and Hand	1	N.B.	M	+	+	+	+
25		2	N.B.	M	+	+	+	+
26	1958 Mitchell and Waddell	1	3½ yrs.	F	+	+	+	+
27		2	5 yrs.	F	+	+	+	−
28	1959 Walls, Altman, and Winslow		6 yrs.	M	+	+	+	±
29	Present case							

† We have excluded the third case of Metrakos and Fraser and the second case of Weyers because they had only two of the elements of the syndrome. Although the case of Debré and associates is analyzed, it is not computed in the statistics because only two of the typical features were present, even though the histopathological findings were characteristic.

septal defects—as determined by the clinical characteristics of the murmur [2,6,22], by complete cardiovascular examination (cardiac catheterization and angiocardiography) [11], and by autopsy [1,3,19,20,25].

The major skeletal lesions as seen on the roentgenogram are in the limbs. Acromelic shortening of the long bones is one of the principal characteristics along with the previously described changes in the hands and feet. The deformities of the proximal end of the tibia are almost pathognomonic of the Ellis-van Creveld syndrome; the metaphyseal border appears angulated in the form of a double-sloped roof, with the outer slope longer than the inner. The epiphyseal nucleus is hypoplastic, being more developed on the medial than on the lateral side with resulting genu valgum.

The laboratory data in the cases reported to date are not of diagnostic value.

The primary pathological lesion appears to reside exclusively in the epiphyseal cartilage [5,11,22,23].

Mental retardation is not characteristic of this syndrome, the reported cases including a college graduate and a severely retarded child [15].

Consanguinity of the parents was reported in eleven of the twenty-nine cases.

In some instances the anomaly would appear to be an inherited characteristic transmitted by a recessive gene or genes, the anomaly appearing with the union of two individuals, both carriers of the characteristic [6]. In other instances [8], although the anomaly was undoubtedly recessive, it could have been the result of an isolated gene or a mutation.

The Ellis-van Creveld syndrome must be distinguished from true chondrodysplasia, gargoylism, and congenital anhydrotic ectodermal dysplasia.

CASE REPORT

L. A. R., a boy, nine years and nine months old, was born at full term after an uneventful pregnancy. His birth was normal. At one year, mental retardation was noted and he had not started to walk. Dentition was delayed. His central lower incisors did not erupt until he was sixteen months old.

There was no history of consanguinity or of deformities suggesting chondro-ectodermal dysplasia in the family. The patient had one brother and two half brothers by a different father. His mother and three brothers were normal. The two fathers were not examined.

Physical Examination

On examination the boy was found to have abnormally short limbs but his head, neck, and trunk were essentially normal with normal dimensions according to the Engelbach tables [38]. His height was 115 centimeters (normal 130 centimeters) and his arm span was 98.5 centimeters (normal 129 centimeters), with most of the shortening in the distal segments (Figs. 1 and 2).

The skull was subbrachycephalic; hair and facies were normal. The two upper incisors and two lower canine teeth were missing. The remaining teeth were dysplastic; only temporary teeth were present (Fig. 3).

FIG. 1

FIG. 2

His upper extremities were acromelic, the shortening increasing in the distal segments. Both hands were as wide as they were long, with a sixth digit on the ulnar side of the hand. Except for the supernumerary digit, which was weak with restricted motion, the fingers had normal mobility and strength, although they were short and stubby.

The nails on the normal fingers were short, small, and fluted. They did reach the ends of the fingers. On the two supernumerary digits, the nails were rudimentary (Fig. 4).

The general configuration of the upper and lower extremities was the same (Fig. 5), but there were no supernumerary digits on the feet. Both fourth toes were longer than the corresponding third toes. All nails were dysplastic, and there was no nail at all on fifth right toe. There were bilateral cavus deformities of both feet.

Eye grounds were normal.

The child was of low normal intelligence with a mental age of eight years and nine months

FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

(chronological age, nine years and nine months) and an intelligence coefficient of 0.9. He was doing well in school. His performance in various psychometric tests (Pitner, Bender, Termann, Merrill, and Goodenough) was satisfactory for his age. He spoke and read without difficulty.

Laboratory Studies

An electroencephalogram showed bradydisrrythmia with medium voltage and no focal discharges. An electrocardiogram was within normal limits.

A routine blood count was normal. Blood cholesterol was 90 milligrams per 100 cubic centimeters (normal 150 to 250 milligrams, Sackett method); the alkaline phosphatase was 4 units (normal 8 to 15 units, King method). Serum calcium, acid phosphatase, and serum proteins were within normal limits. Wassermann and Kahn tests were negative, as was the Mantoux reaction. The basal metabolism rate (Du Bois method, as modified by Boothby and Sandiford) was −8 per cent.

Roentgenographic Studies

The skull (Fig. 6) was normal for his age. Unerupted upper incisors and lower canines were visible.

FIG. 8

FIG. 9

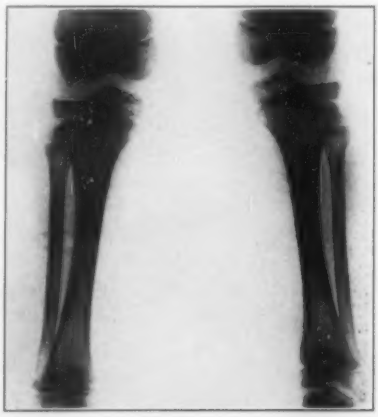

FIG. 10

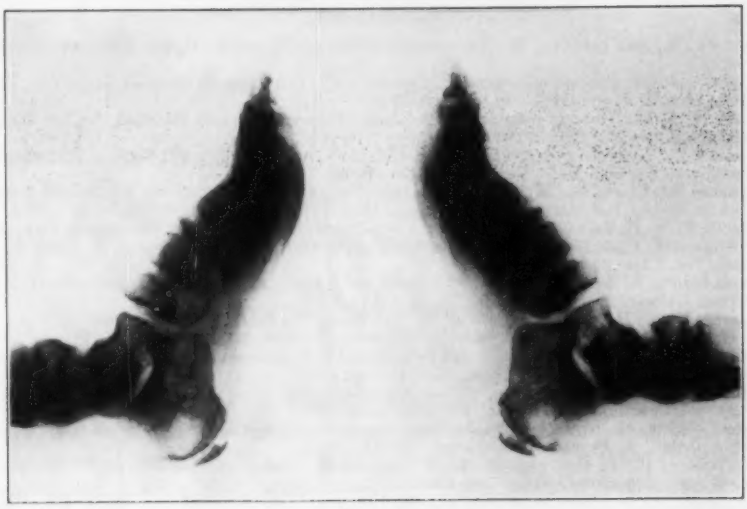

FIG. 11

The spine, ribs, sacrum, and pelvis were normal except for hypoplasia of both acetabula (Fig. 7).

In the upper extremities, there was some widening of the metaphyses and diaphyses of the long bones, as well as shortening (Fig. 8). The humerus was 20.3 centimeters long (average normal, 24.72 centimeters); the left ulna was 13.5 centimeters (average normal, 19.8); and the left radius was twelve centimeters (average normal, 18.1 centimeters)[14]. The center of ossification of the proximal radial epiphysis was not visible (normal age of appearance, approximately six years.)

In the hands, there was synostosis of the capitate and the hamate (Fig. 8). The bone age was equivalent to the chronological age. The supernumerary metacarpal was fused to the adjacent normal fifth metacarpal. There were pseudo-epiphyses at the proximal ends of both second metacarpals similar to the pseudo-epiphysis recorded by Caffey. In addition, there was a distal pseudo-epiphysis on the first metacarpal. Similar anomalies were present in his elder brother but not in his two younger half brothers. The phalanges were normal except that the terminal phalanx was missing in the supernumerary digits.

In the lower extremities, there was bilateral coxa valga (Fig. 7) with a neck-to-shaft angle of 151 degrees (normal, 130 to 140 degrees), and shortening of both femora which measured 26.5 centimeters in length (normal average, 35.3 centimeters).

The proximal tibial epiphysis showed the typical changes of the Ellis-van Creveld syndrome: hypoplasia of the ossification center and angulation of the epiphyseal border due to the greater development of its medial half. In the distal tibial metaphysis, the irregular sclerosis of the spongiosa characteristic of this syndrome was noted (Fig. 9). Both tibiae were short (Fig. 10) when compared with the normal average of 29.37 centimeters; the fibulae were also short—16.5 centimeters (normal average, 28.7 centimeters).

In the foot, the bones were normal except for the cavus deformities, and the bone age, as shown by roentgenograms of the feet, was equivalent to the chronological age (Fig. 11).

SUMMARY

A case of Ellis-van Creveld syndrome (chondro-ectodermal dysplasia) is reported in a boy, nine years and nine months old. The main findings were polydactyly (both hands), ectodermal dysplasia (teeth and nails), and typical chondrodystrophial lesions. Congenital cardiac anomalies were absent. All studies, including the hemogram, blood chemistry, electrocardiogram, electroencephalogram, and psychometric and ophthalmoscopic examinations were normal. There was no consanguinity or genetic antecedents of the process in the parents. One brother and two half brothers were normal. From a review of the literature, this would appear to be the twenty-ninth case and the first reported from South America.

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Bilateral Peroneal Spastic Flat Feet Associated with Congenital Fusion of the Navicular and Talus

A Case Report

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Anomalies of the tarsal bones are quite frequent. Since 1948, when Harris and Beath first stressed the significance of these anomalies in the causation of symptomatic flat feet, numerous articles [2,5,6,7,8] have appeared in which the various anomalies—osseous, fibrous, and cartilaginous, either partial or complete—were described and the symptoms and significance discussed.

The case to be reported describes a patient with bilateral talonavicular fusion associated with symptomatic peroneal spastic flat feet. Although talonavicular fusion was previously reported [1,2], we have been unable to find any similar case of bilateral talonavicular fusion producing peroneal spastic flat feet.

FIG. 1

Standing photograph showing flattening of the longitudinal arches.

CASE REPORTS

J.B., a white male truck driver, twenty-nine years old, was seen in the senior author's office on January 30, 1961, complaining of severe pain in the right ankle and in both feet. The patient walked with a slight limp on the right side and said he had had painful flat feet since childhood. He had consulted numerous physicians but had not been helped by any conservative therapy. He wore arch-support shoes, which enabled him to engage in his present occupation. Sometimes when his work became more arduous and he had to move heavy packages or when he jumped from a truck, the pain in his feet became so intolerable that he was forced to discontinue work for a few days.

On examination, the patient was tall, and although overweight, was well built, with good muscle development. Symptoms of pain were severe in the right foot, as compared with the left. There was no history of acute trauma or any antecedent sickness or disability. Both feet showed marked pes planus with rigidity and severe peroneal spasm (Fig. 1). Tenderness was present over the anterior aspect of the lateral malleolus and peroneal tendons. Tightness and a bow-string effect of the tendons were noted with some soft-tissue thickening about the ankle joint above the lateral malle-

olus. The head of the talus, which occupied the usual position of the navicular, was prominent on the medial aspect of the foot; almost complete loss of the longitudinal arch was apparent in both feet. The thickened medial plantar fat touched the ground on weight-bearing; the medial side of the shank of the shoe was flattened to the ground. Inversion and eversion of both feet were limited and painful, more so on the right side than on the left. No neurological deficit or muscle weakness was found. There was slight hallux valgus with limitation of extension of the big toe. Roentgenograms revealed marked bilateral pes planus. The trabecular pattern of the bones of both feet was prominent and the navicular bone was absent in both feet (Fig. 2). The talus showed marked enlargement with elongation and widening of the neck; the anterior articular surface was irregular with

FIG. 2

Lateral roentgenogram of the left foot showing clear bone trabeculae extending the length of the neck of the talus; the navicular is absent.

FIG. 3

Lateral roentgenogram of the right foot. Stieda's process is poorly mineralized and not clearly visible; absence of the navicular is again demonstrated.

prominent lipping and projections. The medial side of the head of the talus replaced the navicular tuberosity (Figs. 3 and 4). The cuneiforms were larger than normal, particularly the medial cuneiform. On the right foot there was an enlarged posterior process of the talus (Steida's process). Slight lipping and sharpening of the lower anterior and posterior articular margins of the tibia was also noted bilaterally (Fig. 2). There were no gross anomalies present between the calcaneus, talus, and cuboid, but the contour of the subtalar joints was irregular (Fig. 5). The subtalar joint was clearly visible. Both feet showed slight hallux valgus and minimum arthritic changes in the metatarsophalangeal joints.

The patient was treated conservatively with procaine and hydrocortisone injections into the synovial sheaths of the peroneus longus and peroneus brevis tendons and into the subtalar joints. His feet were strapped in eversion and exaggerated valgus position for three weeks. Active exercises and hydrotherapy were then started, and rigid, double-sole shoes with arch supports were prescribed. The patient became asymptomatic following this regime.

On July 20, 1961, when the patient was last seen, he had no symptoms and had complete relief of pain. He mentioned, however, that occasionally his feet became tired after heavy work or walking on an irregular surface. On examination, he had neither spasm of the peroneals nor any of the tenderness previously described, but motion of the subtalar joints was very slight. No surgery was indicated.

DISCUSSION

Hark reported that congenital fusion, fibrous or osseous, is seen between the talus and navicular, but often is of not much clinical significance. On the other

hand, congenital anomalies of the subtalar and calcaneonavicular joints frequently are symptomatic. He emphasized, as did other authors [4,6], that talocalcaneal anomalies are more symptomatic and more likely to give rise to peroneal spastic flat feet. The presence of Steida's process and irregularity of the shape of the talus in that area also produced symptoms.

The patient in the present report did not demonstrate any subtalar anomalies except the presence of Steida's process on the right, which could not account for the bilateral symptoms but may account for the severity of symptoms on the right.

Outland and Murphy [8], in their classification of the congenital tarsal anomalies which produce peroneal spastic flat feet, listed anomaly of the navicular but did not mention absent navicular or fused talonavicular bone. In their discussion of the pathomechanics of peroneal spastic flat foot, they postulated that the peroneal spasm was due to "molding changes in the talonavicular joint". In our patient, since this joint was not present, the origin of peroneal spasm cannot be explained on that basis.

FIG. 4

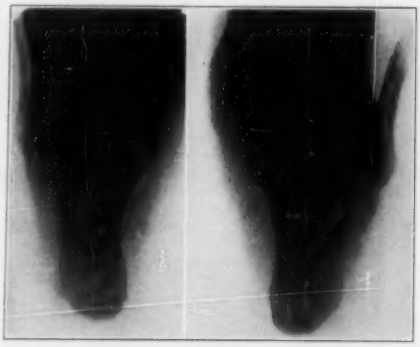

FIG. 5

Fig. 4: Anteroposterior roentgenogram of both feet. Note the irregular shape of the head of the talus and talar tuberosity which replace the navicular.

Fig. 5: Axial view showing the irregular contour of the subtalar joint, but no evidence of a talocalcaneal bridge.

We believe that during weight-bearing the disturbed mechanics of the foot, the result of the abnormal configuration of the bones, lead to synovial irritation in various joints, particularly the subtalar joint. The peroneal tendons, enclosed in their synovial sheaths, are in close proximity to this joint behind and below the lateral malleolus and also become irritated, producing a traumatic tenosynovitis. During walking on an uneven surface, the flattened longitudinal arch, the irregular articular surface of the talus and calcaneus, and the abnormal excursion of the peroneus longus and peroneus brevis tendons further irritate the subtarsal joint and cause pain. This, in turn, produces spasm of the peroneals and further increases the valgus and pronation deformity of the feet. In the event of complete obliteration of the subtalar joint by disease or surgical fusion, no further irritation of these tendons or muscle spasm can occur and pain ceases. Peroneal spasm in congenital anomalies is seen only in association with partial fibrous or bone bars which allow some subtalar motion.

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Stockinet Head Halter

BY AVRUM FROIMSON, M.D., CLEVELAND, OHIO

From St. Luke's Hospital, Cleveland

Head-halter traction is widely used in the care of neck disorders. An effective, comfortable head halter can be easily made from inexpensive orthopaedic stockinet to substitute for a prefabricated canvas halter, in many circumstances. This improvised device also has some special advantages and applications.

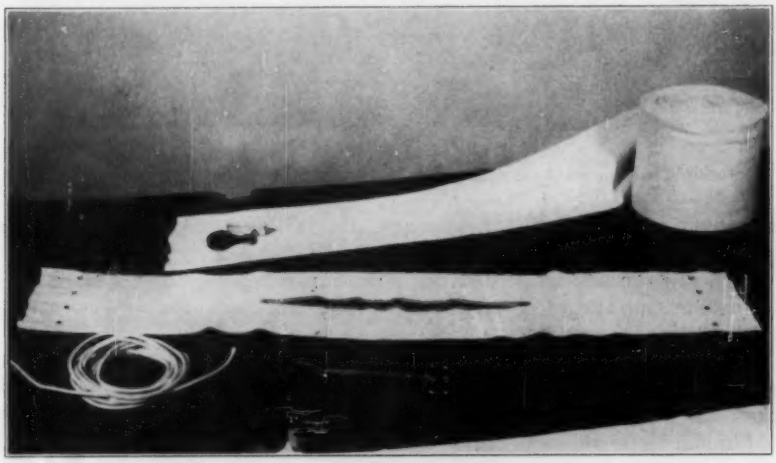

FIG. 1

Halter marked and cut from roll of stockinet. Rope and pulley to be supplied to patient for home traction kit.

A thirty-inch length of six-inch wide orthopaedic stockinet is used. For an adult of average size this is split longitudinally in the middle for a distance of eleven inches to bifurcate at the top of each ear and fit under the occiput and mandible (Fig. 1). One to two inches from each end of the stockinet halter, four evenly spaced holes are made by spreading apart the knitted threads. (If these holes are sharply cut they tend to rip further when traction is applied.) A traction cord is then passed through all of the holes as the stockinet is gathered into accordion pleats. As the halter is adjusted to the chin and occiput, traction is applied through the rope. Stockinet stretches slightly to conform to the contours, resulting in relative freedom from chafing. A spreader bar may be used. If it is desired that the neck be flexed during the traction, the occipital pull can be increased by placing the rope holes nearest the posterior border further from the end of the stockinet.

This device was originally made to provide inexpensive home traction kits for ambulatory patients with neck symptoms. A small pulley purchased in a hardware store is fixed to an overhead door frame. Traction is provided by a partly filled water bucket or suitcase, or a weighted sling is made from stockinet.

This halter is now also used in the emergency handling of neck injuries for partial immobilization and relief of muscle spasm (Fig. 2). In addition to its comfort, low cost, and ready availability, the stockinet halter has the advantage of permitting

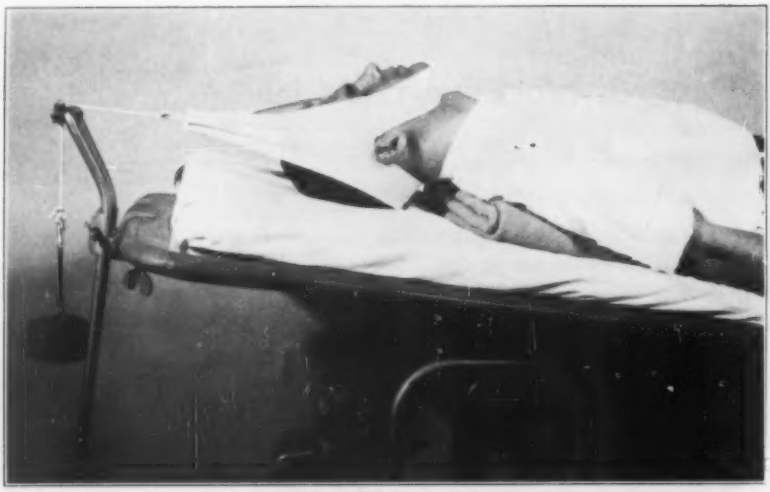

FIG. 2

Stockinet halter used in emergency care with standard stretcher pulley and weights.

roentgenograms to be made of spine and skull without interference from metal buckles. The halter can be laundered or discarded if soiled.

A head halter should be included in an emergency bag so that traction immobilization can always be improvised before transporting a patient with an injured neck.

This head halter can be used to apply traction and then incorporated in the cast as additional padding when applying a Risser localizer jacket or Minerva jacket.

Standard materials can often be adapted to substitute for unavailable or costly apparatus and in some instances these improvisions are found to possess unique features and applications.

Orthopaedic Stroller Chair

An Aid in the Treatment of Congenital Dislocation of the Hip

BY DAVID W. FLORENCE, M.D., AND MARVIN A. CAPLAN, B.S., BOSTON, MASSACHUSETTS

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Many problems arise in the care of a small child confined within a plaster spica cast. Soiling or softening of the cast by feces or urine is perhaps the most common problem. In addition, the patient in a plaster spica must usually be in bed, either prone or supine on a frame, assuming the upright position only when held for feeding or for short periods of play. Inevitably, the child is partially isolated from the center of family activity because of the cumbersome task of moving the frame from room to room. Owing to the length of confinement, this isolation may affect normal social development, and the limitations on self-feeding

FIG. 1

and play imposed by existence on a Bradford frame may likewise be retarding. Last, but not least, immobility of the young patient in a plaster spica is a hardship for the mother who must constantly carry the child and the cast, a burden that increases as the child grows.

To overcome these problems in the care of his own child, a girl with congenital dislocation of the hip, one of us (M.A.C.) developed a device that provides for support of the child in the sitting position, acts as a stroller, and may be converted to form a seat in an automobile.

The complete unit (Fig. 1) is made up of five components: adjustable table-

FIG. 2

FIG. 3

FIG. 4

top, aluminum supporting frame, fiber glass shell, stroller base with pusher, and car-seat bracket. In its present form the device will accommodate a child weighing from twelve to thirty-five pounds.

The tabletop is hinged and fitted with a catch so that when it is in place in the horizontal position it will not move (Fig. 3), yet it can be readily moved out of the way (Fig. 4) when the child is put into or removed from the device. The table is also adjustable in the horizontal plane to accommodate spicas of different sizes. A locking mechanism is provided to hold the table rigid in the desired position. Once the table is locked in position it is impossible for the spica to move, and the child is thus held securely in the upright position.

The aluminum supporting frame (Figs. 3 and 4) can be placed on the floor, resting on non-marking rubber feet. A backrest attached to the posterior uprights can be adjusted by two wing nuts (Fig. 1). These permit wide adjustments of the distance between the backrest and tabletop, thus making it possible to lock the child and the cast solidly in the chair at the desired sitting angle (Fig. 2). Once adjusted, no further adjustments need to be made for any one cast. The table is merely lifted up and down when the child is removed from the chair or placed in it.

The fiber glass shell, which is solidly attached to the aluminum supporting frame, will accept a frog-leg spica cast with the hips in a variety of positions. The body of the cast is gripped by the table and backrest; the right and left cutouts in the shell will accommodate the leg portions of the cast even when the hips are in considerable flexion or in less than 90 degrees of abduction. The edges of the shell where they bear on the cast are covered with rubber extrusion for cushioning.

The bottom section of the shell makes the stroller chair a commode. By means of a handle in front of the bottom section, it can be slid forward and removed easily for emptying and cleaning. With the child in position, the bottom section in the closed position, and the table and backrest in place, soiling of the cast is virtually impossible, and the interior of the bottom section is completely concealed.

The stroller base with pusher is fitted with channels on which the supporting frame is fixed by four cut-outs, into which the rubber feet fit, and by two spring-loaded clips, one in each channel (Fig. 1). The chair with the frame is easily attached to the stroller base or removed from the stroller simply by setting or releasing the clips, a process which involves lifting and rotating each clip 90 degrees. The pusher is hinged and can be folded into the stroller to facilitate storage and packing in an automobile trunk.

The car-seat bracket (Fig. 1) can be used to anchor the chair with its supporting frame securely to the back of a car seat. The aluminum bracket is hooked over the back of the car seat and its two straps are clipped to the supporting frame of the chair which rests on the car seat. Since the table is not ordinarily used when the seat is in a car, an auxiliary strap is supplied which is buckled around the body of the cast to hold it in place.

At the time of writing the device had been used by forty-seven children and the design was modified several times. In all but three children the chair was satisfactory. In these three the position of the hips was so asymmetrical that the child could not be maintained in a perfect upright position, and the side slots in the fiber glass shell were padded to adjust for the asymmetrical position of the legs. In all instances, therefore, any such asymmetry was readily compensated for by the use of padding.

Depending on the age and development of the child, the stroller may be used during the waking hours. At night and during rest periods a Bradford frame is used with the cephalad end elevated 20 to 30 degrees, as is the established practice at the Children's Medical Center in Boston. Used in this way the stroller chair, in our experience, has contributed substantially to the mental and physical well-being of both mother and child.

NOTE: The authors wish to express their appreciation to Mr. Richard Panicci for his contributions toward the present design of the apparatus.

Portrait of Nathan Smith (1762–1829) done in 1825 by Samuel Finley Breese Morse, owned by Yale University. Morse, an accomplished artist, is better remembered as the inventor of the electric telegraph. (The painting is reproduced through the courtesy of Yale University Art Gallery.)

Nathan Smith (1762-1829) on Amputations*

BY MATHER CLEVELAND, M.D., AND OLIVER S. HAYWARD, M.D.,
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At the beginning of the nineteenth century the two greatest surgeons in New England were John Warren at Harvard and Nathan Smith at Dartmouth [4]. Smith had been a student of Warren at Harvard in 1790, receiving his M.B. degree. He had also trained under a fine Vermont surgeon, Josiah Goodhue (who subsequently became President of the Berkshire Medical School), and in 1797 he had spent a year in the clinics of Edinburgh and London. He became the first professor at his own Medical School at Dartmouth in 1797 where he remained until 1813. For most of these sixteen years he held the Professorships of Anatomy, Physiology, Chemistry, Theory and Practice of Medicine, and Materia Medica. From 1813 until his death in 1829 he was the first Professor of the Theory and Practice of Physic, Surgery and Obstetricks at the newly founded Yale Medical Institute.

For the most part, his surgical thinking was his own. He read widely throughout his professional career, accepting what was sensible from the authorities, especially the treatises of Benjamin Bell, but never hesitating to disagree with them [5]. He devised many surgical procedures and instruments himself: a new flap for the closure of amputation stumps, a corrective operation for harelip, an oophorectomy [8], an operation for imperforate anus, procedures for the treatment of ununited fractures and osteomyelitis [7], operations for cataracts, aneurysms, and cancer [6], a splint for fractures of the thigh, an extractor for foreign bodies in the esophagus, and a new maneuver for reducing dislocated hips.

All of these procedures involved modern ideas of surgery [1]. We are fortunate to have details from lecture notes carefully and elaborately made by a dozen of his students both at Dartmouth and at Yale. The most extensive notes are those of Worham L. Fitch [3] who studied under him at Yale in 1825–26 and later became a surgeon in Springfield, Massachusetts, where he was in general practice until his death in 1872 at the age of sixty-nine [2].

From internal evidence Dr. Fitch's lecture notes seem to have been taken down almost verbatim. Then, before the next lecture, they were read over, presumably by Nathan Smith himself (since some of the corrections were signed *Smith*); pencilled corrections were made; frequently a *Note* was added and then the whole note was inked over with pen and ink.

There follows the entire series of lectures on amputations exactly as taken down by Dr. Fitch with the occasional correction of a misspelled word:

LECTURE 8TH

AMPUTATION OF THE LIMBS

I shall at this time say but little on the cases that require amputation. I shall only give some general rules.

The operation is generally performed to save life; but it may be performed in cases where it would not be necessary to save life. For instance it may be necessary to take off a curved finger in consequence of anchylosis. Sometimes a finger becomes anchylosed in a straight direction and then it is still worse than if

* With the help of National Institutes of Health Grant R6-6625.

curved. It may be so with a leg. The hands and feet are not alike in this respect. If you can save one finger it will be best to save it. It is not so with a foot. The taking off half a foot I believe would be improper. A part of the foot may be taken off transversely but not in longitudinal direction. It would be more convenient walking on a wooden one. A part of a hand would be of great use.

In general the amputation of a large limb is performed to save life. You should not be too hasty in performing it. The first thing to be attended to in amputation is to restrain the blood and prevent the circulation in the part. For this purpose several kinds of tourniquets have been used. It may be necessary to tighten the tourniquet several times during the operation, and the common tourniquet is liable to become a *ne plus ultra** before sufficient pressure has been made to stop the blood. The strap is liable to tear upon the buckle. I have invented a tourniquet which is not liable to the objection of the common screw tourniquet. It will not come to a *ne plus ultra* before the operation is finished. With this you can draw the strap to any length, but you cannot pull with so great a force as with a screw tourniquet, but can generally draw with sufficient force to stop the blood.

The strap is wound upon an iron roller to which is affixed a handle like that of the common tooth instruments and a spring prevents it from unwinding. Neither of these are of any use.

The best tourniquet is a handkerchief folded and tied around the limb. It is well to let the knot come upon the artery. Then with a stick twist the handkerchief till the circulation is stopped. This will never break and there is nothing that will give way. A tourniquet is liable to break; if this should happen you can generally catch hold of the end of the artery when it is first cut off. By catching hold of the artery you can stop the hemorrhage with slight force but it requires a great degree of pressure.

The amputation of a limb is a very simple operation; but as it is but seldom performed, it has been supposed that extraordinary means should be used. Many needless instruments have been employed.

The first method practised was to cut and sew. After cutting off the limb hot iron was applied to prevent the hemorrhage. The iron was applied over the whole surface of the wound.

It was often practised to take up and tie the artery which was done by passing a needle in a circular direction round the artery taking up with it considerable flesh. This was thought to be necessary to prevent the ligature from cutting the artery. Arteries tied in this way would sometimes bleed again and it always produced a great deal of pain.

No doubt this was a cause of many failures in operations of this kind and caused lockjaw and other accidents.

Much has been said about ligatures, their form and size &c. Some recommend silks, some linen and some leather. Some say they should be flat. All that is necessary is that it should be a small string, the smaller the better if of sufficient strength, and it should be drawn so tight as to destroy the vitality of the end of the artery.

It is said that leather will dissolve in the wound and that it will not be necessary to remove it. I have no doubt but this may be successful. An artery should not be tied with a surgeon's knot, but with a common double knot. You should continue for a considerable time after tying the first knot, say half a minute before you tie the other. If the ligature is well waxed it will not yield while you

* "A limiting condition" — Webster.

are tying the 2d. If you kill the end of the artery there will be no trouble in taking away the ligature.

I think a good practice is to cut off one end of the ligature near the knot, and then we have but one to pull out. This is of no great consequence. I do not think it of much consequence to have a ligature that could not be taken out, or that will be absorbed as it is said that leather will.

No force should be used in taking away the ligature.

To take up an artery use a *tenaculum*. Run it through both sides of the artery, and then apply the ligature behind it. If a larger artery is to be tied draw it out a little with the tenaculum. You are much cautioned against tying the nerve with the artery. I should not want to do this; but I think it is not of so much consequence as has been supposed. In the old method of taking up arteries when they enclosed a large quantity of muscle, nerves have been often taken up with them, yet no serious injury followed.

Form of the Knife. The first operation I performed I operated with a knife in the form of a sickle. The edge ought to have been on the other side. This was soon found inconvenient, and a straight edge was chosen. The knife must be long. The edge being straight is of no inconvenience; but the knife will cut easily if the edge is a little convex. In my mode of operating a long knife is most convenient. It has been practised (and is now by most) to cut directly around the limb.

I cut two flaps in the form of a half circle. If the work is well laid out there will be no difficulty in making the angles meet. In the old method bad stumps were made by either too much or too little of the soft parts being left. This would always be the case where there is no rule but the judgement of the operator. This would never be the case in my mode of operating.

The best mode in applying the tourniquet on any of the extremities is to press the artery when it passes on the limb and hold the limb up & the veins will convey the blood principally out of the limb. Then apply the tourniquet. You will have but little blood in the operation.

LECTURE 9TH

AMPUTATION (*continued*)

As a general rule you should save all the stump you can. It is better to amputate low down towards the ankle than high up where it can be done and remove the disease. A person can walk on the stump with wooden feet better when both legs are operated upon low down than when it is done above the knee; he will not be obliged to go upon his knees as has been supposed.

I have seen an instance where a man had his legs amputated below his knees and he walked upon the stumps and not upon his knees. It is not necessary to amputate the whole limb from a sinus extending up the thigh as sometimes happens when the knee is diseased. I have cut across sinuses several times and it was productive of no ill consequences.

When a bone is diseased and a part of it seems to be sound above, it is not safe to cut through the bone, but you should take the whole bone away. When the disease is seated in the joints there is no danger in cutting near it.

All operations should be performed with a sharp knife. No great inequality should be made on the stump. You should cut so as to have every part meet its fellow. Muscles should meet muscles. The outside cuts should be equal and uniform so as to meet exactly. Sawing the bone is attended with but little difficulty; but care should be taken not to shiver the bone. If any shivers remain after sawing the bone they should be removed. A little inequality will be of no great injury.

The ligatures should be strong, firm and hard. As to the shape whether flat or round is immaterial. They should be made small and they will not be so likely to get loose afterwards.

Note. In operation of the extremities there is some motion in sawing the bone which makes it difficult. Sometimes you can remedy this by putting a small block under the limb and to have the limb over the place where you wish to divide the bone.

AMPUTATION OF THE TOES

This is a simple business. I have never used a tourniquet except for the great toe. In amputation of the toes it will be well enough to mark the place where you wish to cut with ink. Commence the incision between the toes, carry it in semi-circular direction over the toe to the outside, then make a corresponding incision on the under side of the toe, bring the angles directly over the joints at the lateral ligaments, then dissect back the flaps and divide the ligaments and remove the toe.

It may be necessary to amputate the foot across the metatarsal bones. When the wound is by scalds, burns &c. it will be better to take it off in this place than the whole foot. When you cannot take it off in this place and have a handsome stump and remove the disease, it will be better to take it off above the ankle. There has not been much said in favor of amputating here. It would be a difficult operation to perform and we should have a tendinous substance to cover the bones.

AMPUTATION ABOVE THE ANKLE JOINT

Make the angles of the incisions anteriorly and posteriorly. Cut through the skin and muscles with the same stroke of the knife without drawing back the skin. Use a common scalpel and no other knife.

If this operation is performed with the angles at the sides, the bone may protrude through the external parts,—it did so in one instance. If the operation is performed with one angle before and the other behind, it leaves a much handsomer stump because the limb is thick in this direction.

Note. Sometimes in amputation at the joints of limbs the cut surfaces of the parts adhere all together but they do not adhere to the joint so that a sac is formed which is occasioned by the synovial fluid of the joint. This is secreted by the synovial membrane of the joint which causes the soft parts to adhere to the joint. In such cases it will be necessary to cut off the cartilage of the joint which can be done very readily with a knife or any other instruments and there will be no difficulty of the soft part healing to the bone.

AMPUTATION AT THE KNEE JOINT

I do not like the amputation just below the knee joint. If the patient is healthy. I prefer the operation at the knee joint. I do not know that I should have any precedent for this operation, but I believe it would be useful in some cases. In performing this operation I always prefer standing with my left hand towards the head of the patient. In amputating at the knee joint there is no sawing and but little muscular flesh to cut. Upon the knee and the hip I make the angles at the sides of the limb.

There have been objections to operations on the joints. They have been thought more dangerous, but I have operated frequently at the joint. I have amputated at the shoulder joint. Operations have been performed at the elbow joint and wrist. All such operations have done well and healed as well as others. In amputating at the knee joint I should believe it best to dissect back the skin and the under side a little before we come to the muscles. This would prevent a

protuberance in the stump by too large a quantity of the muscles and the stump would be handsome. We have in this operation to cut through very little muscle. In dressing, fetch the flaps together as in other amputations and apply adhesive plaster or straps. The patella will be between the condyles of the os femoris.

AMPUTATION OF THE THIGH

If nothing forbids, operate as low down as can be and leave a good stump.

Stand upon the left side, cut first on the under side to prevent the blood from running down, and covering the marks where you are to cut. In amputation of the limbs measure the limb by a piece of paper passed around it. Then double the paper exactly in the middle and then with a pair of dividers strike a half circle whose greatest diameter is equal to the width of the paper that is doubled, and use this paper as a pattern to mark by upon the limb the place where you are to cut.

Note. If you use the long knife you may begin the incision by putting the point of your knife at one of the angles & pass the knife to the bone and then carrying the knife through & follow your mark. It is not so painful to the patient, & is as equal as good as the other.

AMPUTATION OF THE HIP JOINT

If I were to perform this operation I would cut down and take up the great artery as it comes out of the abdomen and then proceed upon the same plan as before.

Make the angle at the sides. I should like a long knife. Cut down directly as before, and then dissect back the flaps, cut off the ligaments and remove the limb. This operation may be necessary and may be sufficient.

AMPUTATION OF THE SHOULDER JOINT

Make an angle before and another behind. I have performed the operation but once. I then put a strong man, a surgeon, to hold the artery as it passed over the rib where he was able to do it perfectly. In cutting off the limb the patient struggled and the artery slipped under his finger; but he immediately pressed on it and stopped the blood.

I then tied it and it gave only one jet of blood before it was secured. The operation was successful.

TREATMENT AFTER AMPUTATION

The wound should be dressed as before shown. The bandages should be drawn only tight enough to keep the dressings on, then the stump should be on a pillow; and it should be watched with great attention for a few hours on the night after the operation.

After the patient gets warm in bed bleeding sometimes takes place from an artery; although all the arteries at the time were apparently taken up. The patient should never be left by the surgeon for 12 hours after the operation is performed. I never lost a patient from hemorrhage after amputation, yet if I had not staid I should have lost two. It was an old rule that the wound should be dressed in three days.

[. . . . . .] says 5 days in warm and 6, 7, or 8 in cold weather. None of these are exactly correct. It should depend on circumstances. In 2 days from the operation the external dressings, bandages &c. may be taken off down to the sticking plaster and wash the parts. On the 4th day the sticking plaster may be removed. After the first dressing the wound should be dressed every other day.

After the operation give opium to alleviate pain and repeat the dose as occasion may require. I never had but one case where it was necessary to bleed after an operation in consequence of inflammation and then it was thought to be owing to drawing the sticking plaster too tight.

I never lost a patient from the operation. All that died, died in consequence of the wound they had received; or the disease with which they were previously affected; or a long time after the operation they have run into consumption. I have operated several times immediately after the wound was inflicted. They did as others.

COMMENT

The indications for major amputations performed by Nathan Smith were for the most part acute major trauma, infection, and arterial insufficiency with resulting gangrene. It is difficult for a present-day surgeon to appreciate fully the difficulty of performing an amputation on a patient without surgical anesthesia. Nathan Smith says nothing in these lectures of the preoperative preparation of the patient for the ordeal, but in speaking of amputation of the shoulder joint, he mentions that the patient struggled during the operation and loosened the assistant's digital pressure on the axillary artery. No mention is made of opium or of generous quantities of whisky before operation, but one may hope that these amputees received such comfort as these medications might have afforded. I recall my grandfather (M. C.) on his mid-New York State farm, in his great old age telling me how he and three other neighbors restrained a nearby farmer while the local doctor amputated his leg. Surgery in these preanesthesia days was rugged for the patient and the surgeon as well.

"If you can save one finger it will be best to save it. . . . A part of a hand would be of great use." This sound advice by Nathan Smith should never be forgotten.

The conservation of circulating blood by draining it out of the extremity prior to application of the tourniquet, as Smith described it, must have been helpful in times when transfusion was not available.

In the ligation of arteries Smith preferred a small waxed string of adequate strength tied with two ordinary knots for a ligature. This non-absorbable ligature, according to practice at that time, was not cut off but led out through the wound. When this ligature had accomplished its function of "destroying the vitality of the end of the artery" with thrombosis of the vessel the ligature was loose and could be removed by gentle tugging.

The use of a paper pattern to determine the proper size of the flaps is of interest. One can scarcely imagine the thoughts of the terrified patient as he watched this pattern being cut.

In amputations below the knee, Smith states that it is better to amputate low down toward the ankle than high up where it can be done and remove the disease. Possibly this opinion was influenced by the fact that some of Smith's patients did not or could not procure the prosthetic devices that were then available as suggested by his comments concerning his patient with bilateral below-the-knee amputations who walked upon his stumps instead of upon his knees. In such a case a long stump adequately covered with good soft tissue and skin would be preferable to the stump resulting from amputation at the conventional site of election for a below-the-knee amputation.

Although Nathan Smith often traveled long distances on horseback or by

stagecoach to operate on his patients, his brief note on postoperative care to the effect that the patient should never be left by the surgeon for twelve hours after the operation is performed indicates a conscientiousness and dedication that few of us can match today. The fruits of this dedication and care are seen in Smith's statement that he had never lost a patient from hemorrhage after amputation but that if he had not remained at hand two would have died. His rules for dressing the wound and postoperative medication furnish additional proof of the infinite pains which a dedicated surgeon took to ensure the comfort and welfare of his patient.

To show Nathan Smith's varied surgical practice his account book for 1800 was analyzed. The following major operations and charges indicate the scope of his surgical endeavors for that year:

Amputating a leg	$20.00
Operation—unspecified	4.00
Lithotomy	4.00
Operation of trepanning	10.00
Extracting a tumor near an eye	5.00
Reducing a fractured clavicle	1.00
Operation—unspecified	1.00
Reducing a fractured leg	3.00
Operation of trepanning	15.00
Extirpating a tumor on a hand	1.00
Operation of tapping	7.00
Amputating a thigh	25.00
Operation on a girl	1.00
Operation for hydrocele	5.00
Extracting an eye	22.00
Operation for fistula in ano	5.00
Operation for hydrocele	5.00
Operation—unspecified	11.00
Operation—unspecified	1.00
Fixing on a truss	1.00
Reducing a luxated arm	2.50
Operation of castration	2.00
Extracting a pin from a child's throat	.50
Reducing a luxated knee	8.00
Operation for bubonocele	12.00
Extirpating a breast	12.00
Operation for a harelip	6.00
Operation—unspecified	20.00
Operation of trepanning	20.00
Dressing a ruptured artery	.25
Paracentesis of thorax	13.00
Reducing a fractured arm	1.00
Amputating a leg	30.00
Extirpating a tumor from a face	1.50
Extirpating a tumor on a side	1.00
Setting a dislocated arm	2.00
Operation for hydrocele	2.50
Operation for harelip	2.50
Operation—unspecified	5.00

Operation—unspecified	6.00
Operation for a hydrocele	10.00
Operation for a stone on a woman	20.00
Redressing a fractured leg	1.00
Extracting a wart	.25
Operation for a boy	2.00
Perforating the bone for a boy (for osteomyelitis)	2.00
His total charges for surgery	$348.00
His total charges for the year for all practice	$1,849.45

There were probably some other cash calls and these would not be listed. Since goods and services cost one-tenth to one-twentieth of present prices, Smith's total income for the year 1800 would perhaps equal a present-day income of $18,000.

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Proceedings

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Annual Meeting of The American Orthopaedic Association was held at Yosemite National Park, California, from May 22 through 25, 1961, under the Presidency of Dr. Edwin F. Cave.

At the Second Executive Session, the new President, Dr. Joseph A. Freiberg, Cincinnati, Ohio, was inducted into office. The following officers were elected:

President-Elect: George W. N. Eggers, M.D., Galveston, Texas;
Vice-President: Winthrop M. Phelps, M.D., Baltimore, Maryland;
Secretary: Lee Ramsay Straub, M.D., New York, N. Y.,
Treasurer: Mather Cleveland, M.D., New London, New Hampshire;
Chairman of the Membership Committee: Julian E. Jacobs, M.D., Charlotte, North Carolina;
Chairman of the Program Committee: John J. Fahey, M.D., Chicago, Illinois;
Chairman of the Exchange Fellowship Committee: J. Neill Garber, M.D., Indianapolis, Indiana.

The new Active Members elected are:
Alexander P. Aitken, M.D., Brookline, Massachusetts
Robert W. Bailey, M.D., Ann Arbor, Michigan
Paul H. Curtiss, Jr., M.D., Cleveland, Ohio
Albert B. Ferguson, Jr., M.D., Pittsburgh, Pennsylvania
Charles F. Gregory, M.D., Dallas, Texas
John James Hinchey, M.D., San Antonio, Texas
John C. Kennedy, M.D., London, Ontario, Canada
Wood W. Lovell, M.D., Atlanta, Georgia
Newton C. McCollough, M.D., Orlando, Florida
Vernon L. Nickel, M.D., Los Angeles, California
Norman J. Rosenberg, M.D., Cleveland, Ohio
Robert B. Salter, M.D., Toronto, Ontario, Canada
Wayne O. Southwick, M.D., New Haven, Connecticut
William F. Stanek, M.D., Denver, Colorado
Frank H. Stelling, III, M.D., Greenville, South Carolina

The new Senior Member is:
Fred W. Hark, M.D., Chicago, Illinois

The new Honorary Members are:
Joseph H. Boyes, M.D., Los Angeles, California
Harrison L. McLaughlin, M.D., New York, N. Y.

Summaries of the papers presented follow:

Traumatic Dislocation of the Hip: Army Experience and Results over a Twelve-Year Period. Col. Ernest A. Brav [1] reviewed the records of 517 patients treated in Army hospitals between 1947 and 1958, with a total of 523 dislocations. Questionnaires were sent to the patients to obtain information concerning subsequent course, present complaints, and existing disability. Each patient was required to submit current roentgenograms of the pelvis, including a lateral view of the injured hip. Two hundred and sixty-two patients with 264 dislocations returned roentgenograms and questionnaires for evaluation.

Dislocations were divided into four types: Type A, anterior (12.3 per cent); Type I, posterior without fracture (44.5 per cent); Type II, posterior with fracture of acetabular lip (32.6 per cent); and Type III, posterior with fracture through the acetabulum or femoral head (10.6 per cent). The findings reported were as follows:

The clinical results in traumatic dislocation of the hip vary not only with the severity of the injury and the promptness of reduction, but also with the duration of protection from full weight-bearing. Protection longer than four months, however, does not seem to be of additional benefit.

Weight-bearing should not be permitted for twelve to sixteen weeks after any type of hip dislocation. Traction should be applied after reduction for a period of three to six weeks, depending on the type of dislocation.

Time of hip motion and the use of ischial-bearing braces have no influence on the end results.

Avoidance of early weight-bearing does not prevent the development of avascular necrosis of the femoral head; but it probably modifies its severity and minimizes the degree of resultant disability.

1. Medical Corps, United States Army, Fort Lewis, Washington.

Early open operation is indicated only if closed reduction is ineffective, reduction is grossly unstable, there is a loose fragment within the joint space, or there is need for exploration of the sciatic nerve.

The existence of a separated posterior-lip bone fragment in the absence of sciatic-nerve involvement is not an indication for open screw fixation provided stable reduction has been obtained. Redislocation was not noted in this group of patients following proper treatment after reduction.

Primary arthrodesis or cup arthroplasty is rarely indicated and only if joint instability necessitates open reduction.

Subsequent reconstructive hip surgery is advisable only if symptoms warrant and not because of changes noted on roentgenograms. Since the symptomatic results are frequently far better than the roentgenographic appearance would suggest, a conservative approach seems justified.

In discussion, Dr. Paul R. Lipscomb [2] emphasized that the patient may consider his result to be satisfactory, although roentgenograms belie such a conclusion, resulting in a delay of proper reconstructive surgery. Some patients, especially with Type III dislocations, would probably benefit from insertion of a prosthesis, mold arthroplasty, or arthrodesis.

Dr. Don E. King [3] reiterated that 20 per cent of Col. Brav's patients in the combined group of Types A, I, and II had excellent or good results despite aseptic necrosis, but no dislocation of Type III with aseptic necrosis had an excellent or good result. He pointed out that a spica cast in abduction, external rotation, and extension may be a surer way of holding the hip with a posterior lip fracture, than traction, which permits flexion.

Intertrochanteric Osteotomies in Osteo-Arthritis of the Hip. Dr. Carlos E. Ottolenghi [4] and Dr. Edgar Frigerio [5] studied the results of 103 intertrochanteric osteotomies, observed over a period of from one to seventeen years.

Operations were performed on osteo-arthritic hips using Pauwels' varus osteotomy, McMurray's osteotomy, derotation osteotomy, and a combination of McMurray's and Pauwels' techniques.

An analysis of the results showed a high proportion of hips with significant improvement, especially in regard to pain.

The best results were obtained with those osteotomies where the neck is put in a varus position and the shaft is displaced inward.

It is possible to obtain 86 per cent good results (73 per cent very good and 13 per cent good) with intertrochanteric osteotomies.

Pauwels' varus osteotomy would appear to give very good or good results in 96 per cent; McMurray's varus osteotomy gave good or very good results in 95 per cent.

In the six hips in which derotation osteotomy was performed, the results were very good in five and good in one.

The incidence of favorable results declined sharply with McMurray's non-varus osteotomy to 70 per cent, of which 55 per cent were very good and 15 per cent good.

Favorable results were observed in 86 per cent of the forty-three hips followed from three to seventeen years after operation, 79 per cent being very good and 7 per cent good.

Improvement in the roentgenographic appearance of the hips, which accompanied the clinical improvement, was very noticeable in some.

It has been concluded that the osteo-arthritic process is progressive, but reversible if the biomechanical conditions of the joint are improved.

Varus-Producing and Derotational Subtrochanteric Osteotomy in the Treatment of Congenital Dysplasia of the Hip. Dr. E. G. Chuinard [6] and Dr. Norman D. Logan [7] reported the results of fifty-eight osteotomies on fifty-six congenitally dysplastic hips, forty-nine of which were dislocated. The average age of the patient at the beginning of treatment was 2.1 years; at operation, it was 4.3 years. The average follow-up was 5.5 years.

Anteversion, measured before and after operation, using the Magilligan technique, was corrected toward normal in each case. The neck-shaft angle was changed at operation to nearly 90 degrees. Follow-up roentgenograms subsequently demonstrated change of the surgically-produced varus neck-shaft angle toward the normal valgus angle as the child grew. The results were graded *good* in 72.5 per cent of the hips, *fair* in 20.5 per cent, and *poor* in 7.5 per cent. There were no redis-

2. 200 First Street, S.W., Rochester, Minnesota.
3. 2351 Clay Street, San Francisco 15, California.
4. Maipu 757, Buenos Aires, Argentina.
5. J. Hernandez, 2222, Buenos Aires, Argentina.
6. 1922 N.W. Johnson Street, Portland 9, Oregon.
7. University of Oregon Medical School Hospitals, Portland 1, Oregon.

locations, and complications were minimal. The incidence of aseptic necrosis was 9.3 per cent.

The authors believe that varus-producing derotational osteotomy improves the stability of the hip by correcting the static and dynamic forces around the hip joint and suggest that early concentric reduction, correction of anteversion, and production of varus will make other reconstructive surgery, such as shelf procedures or open reductions, less often required in the treatment of congenital dysplasia of the hip with dislocation.

In discussion of the previous two papers, DR. WALTER P. BLOUNT [8] said that he prefers an intertrochanteric osteotomy to a subtrochanteric one. He uses two Schanz screws for fixation in the child from three to eight years of age and internal fixation for the older child. He likes blade-plate fixation for valgus osteotomy but not in varus osteotomy without displacement. He reserves varus osteotomy with medial displacement of the shaft and anterior angulation at the osteotomy site for those patients with free abduction, extremely limited adduction, and antalgic gait. He does valgus osteotomy with medial displacement and anterior angulation at the osteotomy site for adduction-external-rotation-flexion deformities. He believes that the V-blade is much more efficient in adults. If there is less than 60 degrees of flexion, he prefers to correct the deformity by tenotomy and manipulation and give medical treatment until the range of flexion is reduced to 30 degrees, when arthrodesis is indicated. In young patients with very bad hips, primary arthrodesis is often the best choice.

DR. H. R. MCCARROLL [9] pointed out that in some cases the improvement following osteotomy of the hip may not be permanent; and that good results have often been obtained with a hip prosthesis, although his follow-up of such cases is still rather short. Use of a prosthesis makes it unnecessary to confine an older patient to bed for three mon[illegible] as Dr. Ottolenghi and Dr. Frigeria found necessary after osteotomy. Turning to the paper by [illegible] Chuinard and Dr. Logan, Dr. McCarroll stated his preference, particularly in children under eight years of age with posterior dislocation or persistent subluxation, for supracondylar derotational osteotomy of the femur, combined with superior acetabular reconstruction if the acetabulum is inadequate.

DR. F. P. DEWAR [10] emphasized that improvement after osteotomy of the hip is both functional and symptomatic in children, but symptomatic improvement alone is the usual result in adults. The reason for this relief of pain in adults is still not clear.

Surgery in Tuberculosis of the Hip. Retention of Mobility. DR. RYOSUKE KATAYAMA [11] reported that he had followed 250 patients for over one year and eighty patients for over four years after surgical treatment for tuberculosis of the hip designed to retain hip motion. In these eighty patients the results were rated *excellent* in nine, *good* in eighteen, and *fair* in thirty-six; seventeen patients were not improved. The disease recurred in eight of the 250 patients followed for over a year.

In Japan, because of social requirements, it is essential to retain motion in the hip, even if this involves considerable time and the danger of joint instability, reactivation of disease, or failure.

In the series reported, chemotherapy was started early before operation and continued for a long period after reconstruction. The period of chemotherapy in the cases presented averaged 10.3 months before surgery and sixteen months after surgery.

All grossly infected foci were removed by extensive surgical exposure and débridement, avoiding removal of uninvolved bone. Some joint instability and incongruity were frequently accepted.

After removal of foci, fascia, OMS membrane (a membrane similar in composition to catgut), or skin was often interposed. An interposing membrane was not used if the foci were localized to a small area.

A single hip spica cast was applied after surgery. Two or three weeks later exercises in flexion and extension were begun. Seven or eight weeks following surgery abduction and adduction exercises were added, using roller-skating apparatus. At this time an ischial weight-bearing brace was applied and the patient was allowed up on crutches. Weight-bearing was begun eight months after surgery.

Early active lesions have had better results than the old and burned-out ones in which the muscles, ligaments, tendons, and fascia had become fixed. However, some improvement in range of motion can often be expected in such cases.

A motion picture was presented which demonstrated the results.

Lymphangiosarcoma Arising in Chronic Lymphedematous Extremities: Report of Thirteen Cases and Review of Literature. DR. HOWARD F. TASWELL [12], DR. EDWARD H.

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10. 170 St. George Street, Toronto 5, Ontario, Canada.
11. Jikei-Kai University School of Medicine, Tokyo, Japan.
12. Mayo Foundation, Rochester, Minnesota.

SOULE [13], and DR. MARK B. COVENTRY [14] discussed lymphangiosarcoma, a rare malignant neoplasm arising from the endothelium of lymphatic spaces. They said that although it has been described as arising *de novo* as well as in association with irradiated lymphangiomata, it is most commonly associated with chronic lymphedema of an extremity.

Stewart and Treves made the original report in 1948 (Cancer, 1:64–81) of six cases of lymphangiosarcoma arising in a lymphedematous upper extremity following mastectomy. Dr. Taswell, Dr. Soule, and Dr. Coventry reported a total of seventy-one cases from the world literature, including thirteen patients from the Mayo Clinic. Eleven of the thirteen patients were women with postmastectomy lymphedema of the upper extremity, one was a young man with congenital lymphedema of the hand and forearm, and one was an elderly woman with idiopathic chronic lymphedema of the lower extremities.

The tumor has a demonstrable causative factor, namely lymphedema. The treatment is directed toward the ablation of the tumor by radical amputation. Cure has been accomplished, but all too frequently lymphangiosarcoma develops in the adjacent chest wall with subsequent metastases and death. An analysis of the pertinent factors regarding the history, time from development of lymphedema to sarcomatous change (sixteen months to twenty-four years), the significance of radiation therapy, the difficulties in pathological interpretation, and survival was presented. In at least 50 per cent of all known cases, death occurred within two years. The authors compared their cases with those they were able to collect from the world literature.

In discussion, DR. J. VERNON LUCK [15] mentioned the rarity of the tumor; its frequently multicentric origin, which is perhaps one cause of the poor prognosis; and its relation to chronic lymphedema. It has probably been frequently misdiagnosed as metastatic adenocarcinoma of the breast. He said he would like to know if heavy roentgen therapy would help prior to forequarter amputation.

DR. C. HOWARD HATCHER [16] underscored the rarity of the sarcoma and the ease with which its appearance might be confused with metastasis from a previously resected carcinoma of the breast.

In closing, Dr. Coventry said that clinically and histologically the tumor probably has masqueraded as metastatic breast tumor and that in histological study of the biopsy material, it is not always easy to differentiate the two. He said one should be suspicious of raised, purplish nodules, either discrete or coalesced, in a lymphedematous arm after radical mastectomy.

End Results of Patellectomy. DR. FRANCIS E. WEST [17] reviewed the clinical results of eighty-three patellectomies in seventy-four patients.

Patellectomy was performed for chondromalacia of the patella; advanced patellofemoral arthritis; comminuted fracture of the patella, with separation of the fragments; and recurrent dislocation of the patella, with degenerative changes in the patella.

The patients were followed from one to nineteen years after operation; 46 per cent were followed more than five years.

The results were evaluated on the basis of motion, strength, subjective symptoms, and functional results, with special attention to the possible development of arthritic changes of the femoral condyles after patellectomy.

The results were excellent in 63 per cent of the patients, good in 19 per cent, fair in 7 per cent, and poor in 8 per cent.

Dr. West concluded that patellectomy is of value in certain instances of severe patellofemoral disease, although subjective symptoms of some weakness and some quadriceps atrophy are common findings in patients following patellectomy. A normal range of motion can be expected after patellectomy with proper postoperative care. In the patients reviewed there was no clinical evidence of progressive arthritic change in the femoral condyles after patellectomy, and the abnormality in the appearance of the knee was mild and noted chiefly on complete flexion.

In discussion, DR. ROBERT I. HARRIS [18] thought that the technical details of operation are important and has come to use chromic catgut alone in a transverse suture which closes the gap left by the removal of the patella. An occasional knee, despite adequate treatment, falls short of expected results because of lack of strong, full, extension or limited flexion.

DR. HARRISON L. MCLAUGHLIN [19] agreed that the consensus is that when this operation is

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17. 2850 Sixth Avenue, San Diego 3, California.
18. 609 Medical Arts Building, Toronto 5, Ontario, Canada.
19. 180 Fort Washington Avenue, New York 32, N. Y.

done well and for good reason, one can expect a very satisfactory result, although not a normal knee. He often leaves a wafer of the anterior cortex of the patella so that the quadriceps mechanism remains intact and early motion can be instituted safely.

Dr. Preston Wade [20] has found similar good results after complete patellectomy, if done where properly indicated, and believes that there has been too much pessimism in the past about the prognosis.

Treatment of Displacement of the Proximal Radial Epiphysis. Dr. John A. Reidy [21] and Dr. George W. Van Gorder [22] reviewed a total of thirty cases of displacement of the proximal radial epiphysis. All thirty patients were seen at either the Massachusetts General Hospital or the Newton-Wellesley Hospital over a period of thirty-five years. All had fractures through the proximal radial epiphyseal plate and ranged in age from six to thirteen years. Displacement was marked in 80 per cent, moderate in 13 per cent, and minimum in 7 per cent. Twenty-two required open reduction; six, closed reduction; and two, simple immobilization.

Follow-up was from one to twenty-one years, an average of six years. The results were estimated on the basis of the amount of flexion, extension, pronation, and supination. There was some restriction of motion in twenty-two of the twenty-nine patients evaluated. Pronation was limited more frequently than supination; flexion and extension were limited only occasionally. The results were rated *excellent* in eleven, *good* in seven, *fair* in five, and *poor* in six. The patients who were nine years old or younger at the time of injury had much better results than those who were older. Nine patients had some increase in the carrying angle. In the twenty-three patients with adequate roentgenograms, the epiphysis after injury showed continued growth in seven, partial fusion in four, premature fusion in eleven, and non-union in one after open reduction. The authors concluded that treatment should be by closed reduction if possible and that if open reduction is necessary, no internal fixation should be used.

In discussion, Dr. Robert I. Harris [18] mentioned the surprising rarity of avascular necrosis of the radial head in displacements of the proximal radial epiphysis, and reported a case of Dr. W. E. Gallie's in which the epiphysis was removed, replaced, and went on to good healing. He believes that open reduction is the treatment of choice since perfect alignment can be assured and re-establishment of the blood supply will occur.

Dr. Harrison L. McLaughlin [19] said he believes that one may remove the epiphysis if necessary after the age of thirteen. He does not hesitate to use internal fixation if necessary to maintain open reduction.

Dr. Preston A. Wade [20] has found that most displacements of the proximal radial epiphysis are minimal and do not require operation. He agreed with the authors that internal fixation should never be employed. He found that if one can reduce the angulation to 30 degrees or less, open reduction is not indicated, and almost complete function will return. He presented a case of non-union following open reduction in an eight-year-old patient, with good function nevertheless at age thirteen.

Non-Union of the Femur, Treated with Intramedullary Rod and Bone Graft. Dr. Edward T. Smith [23] described nine cases of non-union of the femur treated by inserting an adequate intramedullary rod, if not already present, and a single massive onlay cortical graft of refrigerated homogenous bank bone fixed by six screws. The screw holes in the graft were made slightly larger than the screws to make sure that the graft was compressed against the femoral shaft when the screws were tightened. No external fixation was used postoperatively, and crutch-walking without weight-bearing was started two weeks after operation. Full weight-bearing was usually possible within six to eight months, depending on the roentgenographic appearance of healing. All the fractures united.

Late-Result Study of Battle Fractures of the Femur. Dr. Joseph D. Godfrey [24] reviewed two comparable series of battle fractures of the femoral shaft extracted from World War II rosters from the Surgeon General's office and from his own personal roster.

Results of 181 fractures treated by traction were compared with those of 171 fractures internally fixed by screws only or by screws and plates. The fractures were compared on the bases of the presence or absence of associated injury; the year of the war and the age of the patient at the time

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23. 6410 Fannin, Houston 25, Texas.
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of wounding; the theater of operation: the level of fracture; the missile producing the fracture; the time intervals between various stages of management; the necessity for a particular method of treatment; the evidence of infection and need for amputation; the extent of hospitalization; the disability award; and the present status of the extremity involved.

The author concluded that there is a place for internal fixation of femoral-shaft battle fractures but it should be reserved for the exceptional case. The better results were in the cases in which treatment was delayed until evidence of sepsis had disappeared.

Dr. Leonard T. Peterson [25], in discussing Dr. Smith's paper, suggested that a plate and short screws are sometimes needed for fixation in addition to an intramedullary rod. He agreed with Dr. Godfrey that internal fixation of battle fractures should be delayed until sepsis has disappeared.

Dr. William A. Larmon [26] believes that torsional motion at the fracture site in a femur is frequently the cause of non-union, and that a cortical graft may prevent this. Many of the men injured in battle had internal-fixation devices inserted within fourteen days of injury. This may be too soon after the original débridement and thus contribute to the poor results.

Dr. Milton S. Thompson [27] said that because of slow healing in fractures of the upper-third of the femur, he prefers to use a bone graft primarily and a wire mattress suture to control rotation if bedcare is anticipated. He used transmission of sound (medial malleolus to pubis) to help detect non-union. In the treatment of men with battle injuries, he believes that tibial traction is safer than supracondylar traction because of the danger of sepsis and stiff knees.

Complete Acromionectomy in the Treatment of Tendinitis of the Shoulder. Dr. George Hammond [28] reported on the results of acromionectomy in twenty-five patients with chronic persistent tendinitis of the shoulder (chronic supraspinatus syndrome) who did not respond to conservative therapy. He said that acromionectomy seems indicated in such patients if the pain is disabling and of long duration; however, the range of shoulder motion must be normal. The operation is not difficult and leaves little cosmetic defect. He emphasized total removal of the acromion and secure repair of the deltoid muscle.

In the twenty-five patients treated, the preoperative roentgenograms revealed calcific deposits in twenty-one and lesions encroaching upon the tuberosity-acromial space in three. Spontaneous absorption of the calcific deposits occurred after acromionectomy.

Twenty-one patients were followed from thirteen to 100 months, averaging twenty-eight months. Results were excellent in twelve, good in six, fair in three and poor in none. Because of the high percentage of excellent and good results, this operation is recommended in a small, carefully selected group of patients with tendinitis of the shoulder.

Dr. Harrison L. McLaughlin [19] was not convinced that one should remove the acromion for relief of pain from a chronic calcareous deposit in a tendon. He has had satisfactory results from merely opening and curetting the offending deposit. It is hard to understand why the abolition of the inflammatory reaction by acromionectomy, if that is what happens, would promote the disappearance of the deposit. Perhaps much of the pain relief is due to release of the coraco-acromial ligament.

Dr. Julius Neviaser [29], from anatomical and clinical evidence, believes that partial resection of the acromion with section of the coraco-acromial ligament gives as good results as complete acromionectomy and, at the same time, a significantly better appearance.

Trends in Trauma. Dr. Harrison L. McLaughlin [19], Guest of Honor.

A Technique for Shoulder Arthrodesis. Dr. Joe B. Davis [30] and Dr. George W. Cottrell [11] described a method of shoulder fusion which utilizes intra-articular arthrodesis, rigid screw fixation, viable bone-grafting, and plaster-cast immobilization. The acromion graft is kept attached to the deltoid muscle and is fastened across the denuded shoulder joint as a vascularized bone graft. To determine the optimum position for arthrodesis, they used preoperative temporary Kirschner-wire fixation, inserting the wires through the humerus into the glenoid under local anesthesia. By this maneuver the patient actually experiences the effect of arthrodesis, and the best position for arthrodesis can be determined. A preoperative plaster cast applied in this optimum position, before the Kirschner wires are removed, is worn by the patient during operation to ensure proper positioning.

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27. Nix Professional Building, San Antonio 5, Texas.
28. 605 Commonwealth Avenue, Boston 15, Massachusetts.
29. 1918 K Street, N.W., Washington 6, D. C.
30. 511 S.W. Tenth Avenue, Portland 5, Oregon.

The authors reported a series of ten patients followed for one to ten years; solid fusion occurred in all. In only two of these patients was the position determined preoperatively. In this series one patient had malposition, requiring osteotomy, and two had elbow stiffness, which was overcome by manipulation.

DR. JOSEPH E. MILGRAM [32] discussed the problem of deciding the best position for fusion. He said that some abduction can be retained and the hand still be brought to the side if the shoulder is fused in slight internal rotation. In male patients he resects the outer three-fourths-inch of the clavicle distal to the attachment of the coracoid and trapezoid ligaments, as a second procedure, after fusion is solid. This shifts the fused segments from the frontal to the oblique sagittal plane, thus ensuring adduction, extension, and internal rotation without losing power. The appearance of the shoulder after this second procedure makes it objectionable in a woman.

DR. JAMES E. BATEMAN [33] was impressed with the use of preoperative temporary wire fixation to "customize" the position of the shoulder for the patient's particular requirements. He has found a posterior approach much more convenient than superior or anterior approaches.

The Anterior Shoulder Approach via the Axillary Incision. DR. JAMES T. LESLIE, JR.,[34] and CAPT. THOMAS J. RYAN [35] described an axillary incision and modified anterior shoulder approach which had been used in thirty-five patients.

They stressed the cosmetic advantages of a non-spreading axillary scar and the additional factors of improved surgical exposure and less operative bleeding.

A motion picture was presented which illustrated the incision and showed the results in several patients twelve months after operation.

The paper was discussed by DR. SAM W. BANKS [36] and DR. JESSE T. NICHOLSON [37]. Dr. Nicholson has also found the axillary incision adequate for a deltopectoral approach to the shoulder joint. He believes that a surgeon should always be aware of Sanger's lines in planning incisions.

The Effect of Growth Hormone on Healing of an Experimental Long-Bone Defect. DR. ROBERT E. ZADEK [38] and DR. ROBERT A. ROBINSON [39] described a method for the production of an experimental standard long-bone discontinuity in dogs for the evaluation of methods of aiding bone repair.

The procedure involved intramedullary fixation of the ulna in mongrel dogs and excision of a three-centimeter portion of the radius and covering periosteum. When this was done, the operative defect was not repaired with bone in any of the seventeen dogs in which the epiphyses were closed at the time the discontinuity was produced. When the same procedure was performed in eight dogs in which the epiphyses were still open at the time of surgery, the radial discontinuity was filled with bone and a new radius was formed.

As an example of the use of this procedure, six adult dogs with closed epiphyses were subjected to the standard operation and then treated with bovine growth hormone, starting on the day of operation, at a dosage rate of one milligram per kilogram of body weight three times a week for four weeks. In all six of these dogs bone was formed in the defect almost closing the discontinuity in four; in two, the radial diaphyses were reconstituted. The eventual possibility of using such a substance clinically to increase the rate of bone healing was suggested by the authors.

The Vascularization of Fracture Calluses in the Rabbit. DR. JAMES B. WRAY [40] studied the processes of vessel proliferation at the site of a closed tibial fracture in 100 ten-week-old rabbits. The animals were sacrificed in groups of six at selected intervals after the fracture. After the vascular system of the limb on the side of the fracture had been injected with red methyl methacrylate, the callus and adjacent tibia were carefully exposed. Some specimens were briefly macerated to expose the external vessel system of the callus, others were cut into thin undecalcified specimens, and one specimen from each group was cut into standard histological sections after fixation and decalcification. Observations were recorded with color photography.

The great majority of vessels supplying the callus of these fractures arose from the soft tissues surrounding the fracture. Vessel ingrowth from the periphery was rapidly followed by the perivascular deposition of bone. By the ninth postfracture day these bone deposits had begun to

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35. Medical Corps, United States Air Force, San Antonio 1, Texas.
36. 104 South Michigan Avenue, Chicago 3, Illinois.
37. 1740 Bainbridge Street, Philadelphia 46, Pennsylvania.
38. Johns Hopkins Hospital, Baltimore 5, Maryland.
39. Johns Hopkins Hospital, Baltimore 5, Maryland.
40. Upstate Medical Center, State University of New York, Syracuse 10, New York.

coalesce, with the result that the entire callus was ossified by the eighteenth day. The phase of maximum vascularity of the callus was reached by the twelfth day; thereafter, the blood supply gradually subsided. By the eighteenth day the blood supply of the healed callus was close to that of normal bone, but bone remodeling continued until as late as fifty-five days after fracture.

In discussion of the previous two papers, DR. ROBERT D. RAY [41] suggested that a mongrel dog is not the best animal for a standardized test because of variable ancestry and the expense of care. Furthermore, a long defect in the radius, even if splinted by the ulna, presents problems of displacement, motion, and external stress that are difficult to control from one animal to another. It is hard to quantitate results with only roentgenographic, gross, and microscopic studies; carefully controlled studies of the effect of growth hormone are needed to draw any conclusions.

Concerning Dr. Wray's paper, Dr. Ray was interested in how much of the vascular tree was perfused with the plastic, and how much the endosteal vessels, if intact, would have contributed to the blood supply.

DR. J. WILLIAM HILLMAN [42] commented on the complexity of the problem of analyzing the effects of growth hormone, including impairing glucose uptake in muscles, immunology, antihormone reactions, waning effect on prolonged administration, and problems of metabolic readjustment, including calcium homeostasis on withdrawal of treatment.

Although Dr. Wray's evidence suggests that soft tissues may be a major supply of new callus, clinically, in segmental fractures, healing is more rapid in an area with more generous medullary circulation.

DR. GEORGE W. HYATT [43] was interested in the dosage of growth hormone used. He recommended careful checks to rule out genetic and other inconsistencies in the mongrel and to control potency and purity of the extract of growth hormone.

He praised the craftsmanship of Dr. Wray's injection technique, but wondered how faithfully the plastic reveals the vascular tree, particularly in the terminal capillaries, in view of the variable pressures and viscosity of the plastic.

The Processes of Tendon Healing within the Flexor Digital Sheath of the Dog. CAPT. AUSTIN D. POTENZA [44] described the healing within the flexor digital sheath of canine flexor digitorum profundus tendons. Seventy tendons were submitted to a standard wound and were repaired as atraumatically as possible by a special experimental technique, using a Bunnell pull-out suture of monofilament stainless-steel wire.

It was found that under these experimental conditions, the flexor tendon is repaired by the cellular activity of the sheath and surrounding tissues. The cells of the tendon proper play no active role in tendon repair. Early in the healing process the synovial layer of the sheath is disrupted, allowing granulation tissue to grow between the tendon ends and into the suture tracts in the tendon. The granulation tissue produces a scar between the tendon ends which effects tendon union. Ultimately, this scar matures so that by the 128th day, the collagen in the scar blends perfectly and imperceptibly with that of the tendon proper. Following the initial formation of granulation tissue, the synovial layer of the sheath is gradually restored. The restoration is complete by the twenty-first postoperative day, except for filmy adhesions along the line of tendon division. These adhesions persist throughout the entire healing process, but remain loose and filmy and do not interfere with the functional integrity of the tendon. Microscopically, healing appeared too immature for active mobilization of the tendon before the twenty-eighth postoperative day. After that time the tendons appeared as though they would function satisfactorily; this was confirmed by gross observations.

In discussion, DR. WALTER C. GRAHAM [45] compared this paper with previous reports by Mason and Shearon and by Skoog. Dr. Graham believes that if a tendon is large enough to carry some of its own blood supply, then it contributes to the cellular proliferation and healing of the tendon ends.

DR. JOSEPH H. BOYES [46] pointed out that, in the past, reports based on experiments on different species and on different tendons in the same species have led to conflicting conclusions and confusion, especially when attempts were made to transpose these findings to the care of human tendon injuries.

The tendons of chickens, as described by Lindsay and Thomson, are structurally and in their type of blood supply more similar to the flexor tendons of man. The process of tendon healing in chickens observed by these authors is more in keeping with the commonly accepted concept of hu-

41. College of Medicine, University of Illinois, Chicago 12, Illinois.
42. Vanderbilt Hospital, Nashville 5, Tennessee.
43. United States Naval Medical School, Bethesda 14, Maryland.
44. Walter Reed Army Medical Center, Washington 12, D. C.
45. 1421 State Street, Santa Barbara, California.
46. 2300 South Hope Street, Los Angeles 7, California.

man tendon healing. The most difficult problem is not how do human tendons heal, but how we can control the healing process so as to maintain the tendon as a *gliding structure*. Experience bears out Mason's recommendation that in repair of a tendon within a sheath, the portion of sheath overlying the site of repair should be removed, although at least narrow pulleys must be left.

Presidential Address: Trauma and the Orthopaedic Surgeon. Dr. Edwin F. Cave [47] (J. Bone and Joint Surg., **43-A:** 582–589, June 1961.)

Sick People in a Troubled World. Dr. Howard A. Rusk [48], Guest of Honor.

The Failed Prosthesis and Its Surgical Management. Dr. Philip D. Wilson, Jr., [49] discussed the clinical manifestations of failure of prosthetic reconstruction of the hip in twenty-seven patients on whom reoperations were performed. The primary complaints were pain, prosthetic wear or breakage, infection, and recurrence of ankylosis. Except for loss of mobility, there appeared to be little relationship of the symptoms to bone absorption, prosthetic loosening or settling, and wandering acetabulum. Marked bone absorption was associated with latent infection or non-infectious inflammation.

Relief of pain and restoration of limited function followed a variety of procedures which included substitution of an intramedullary type of prosthesis for a straight-stem type that had failed (eight patients), simple removal of the prosthesis (eight patients), removal followed by subtrochanteric osteotomy (five patients), arthrodesis (three patients), and reconstruction of the hip by placing the stump of the neck or greater trochanter into the acetabulum (three patients). The indications, merits, and faults of each type of procedure were evaluated by the author.

In discussion, Dr. Otto E. Aufranc [50] stressed the importance of studies such as this in improving results and pointed out that any reconstructed joint is always a second-best joint. The recuperation after such an operation involves bone healing. It is therefore important to protect the joint from full weight-bearing for from six months to two years to allow proper healing.

Dr. Chalmers R. Carr [51] found very little relationship between the reason for which hip prostheses are inserted and failure. Pain is sometimes relieved by reinserting a slightly smaller prosthesis. He and his associates have had no dislocations since they began using the posterior approach. As a salvage procedure they have also achieved good symptomatic relief by removing the offending prosthesis, in effect performing a Girdlestone procedure. He agreed that fusion should be reserved for younger patients in whom the prosthesis has failed.

Bilateral Iliac Osteotomy. Dr. E. Harvey O'Phelan [52] discussed the orthopaedic deformities associated with congenital exstrophy of the urinary bladder and described an operation utilized by him and his associates with a partial correction of this malformation. The procedure is carried out in two stages. Initially, bilateral, slightly oblique osteotomies extending from the crest of the ilium to the sciatic notch are performed. Approximately one week later, through an anterior approach, the fixation of the symphysis pubis in as normal reapproximation as possible is accomplished by temporary wiring or placing fascia in this articulation. Seventeen patients ranging from six months to seven years of age were operated on. The longest follow-up extended over three years and no disturbance in growth of the ilium was observed. The complications included complete loss of correction in two patients. The major difficulties have been associated with the wiring of the symphysis pubis. In all patients a partial urethral obstruction was observed, along with some loss of the original correction. Urinary fistula, bladder and ureteral calculi, and ureteral reflux have been the main complications from a urological standpoint. In the majority of the older patients there has been some improvement in control. The bladder has been retained in the pelvis in all but two patients, and the gait has remained stable.

In discussion, Dr. Theodore H. Sweetser [53] emphasized the great advantage of a team approach to problems of exstrophy of the bladder by the appropriate surgical specialists, and showed slides which demonstrated how Dr. O'Phelan's technique had simplified soft-tissue reconstruction.

Dr. John H. Moe [54] congratulated Dr. O'Phelan on his technique and results.

Osteotomy of the Fused Scoliotic Spine. Dr. Bruce J. Brewer [55] presented a method of osteotomy of the fused scoliotic spine to be used after fusion has occurred in too much angulation.

47. 275 Charles Street, Boston 14, Massachusetts.
48. 400 East 34th Street, New York, N. Y.
49. 535 East 70th Street, New York 21, N. Y.
50. 266 Beacon Street, Boston 16, Massachusetts.
51. 1822 Brunswick Avenue, Charlotte 7, North Carolina.
52. 91 South Seventh Street, Minneapolis 2, Minnesota
53. 78 South Ninth Street, Minneapolis 2, Minnesota.
54. 416 Marquette Bank Building, Minneapolis 2, Minnesota.
55. 2040 West Wisconsin Avenue, Milwaukee 3, Wisconsin.

The procedure entails transection of the fused lamina in the interpedicular area, without disruption of the fused articular processes. The fusion mass is cautiously shaved off with a gouge or osteotome until the ligamentum flavum is exposed, after which complete transection of the column is performed. It is sometimes necessary to free the ligamentum flavum and expose epidural fat for complete mobility, but this is performed safely under direct vision. Either a straight transection or a double-wedge resection osteotomy is used. In the wedge resection the center piece which serves as a pivotal point is fractured with a spreader. The correction may be immediate with a block of bone inserted on the concave side or, if preferred, correction can be delayed, placing adequate bone grafts obtained locally at the osteotomy site. Postoperative correction is with the Milwaukee brace, turnbuckle cast, localizer cast, or a combination of these methods. Correction of the curve is best accomplished by two osteotomies, one above and one below the apex of the curve, converting the fused column into three mobile segments.

The results of eighteen operations performed by four surgeons were presented. There were thirteen cases of fused paralytic curves (all residua of poliomyelitis), three cases of fused congenital scoliosis, and two cases of fused idiopathic scoliosis. Pseudarthrosis was found at surgery in four spines and was treated as if it were an osteotomy. Correction was from 9 to 58 degrees (Ferguson method), averaging 27 degrees, with a median of 20 degrees. There were no deaths, operative infections, neurological complications, or pseudarthroses.

Dr. Joseph C. Risser [56] commended the author for presenting a method of salvaging the unfortunately treated scoliotic patient. He cautioned that this is useful in a few cases, but is not the regular pattern of treatment, since early correction and maintenance of correction should make osteotomy unnecessary. He thought that transverse osteotomy with the hinge on the convex side results in great traction and minimum lateral bend. The double-wedge osteotomy would therefore be preferable, although there seems to be no need for a wedge resection on the concave side. The elected sites for the corrective osteotomy should be in the more mobile areas of the lower thoracic and lumbar spine. Five of the patients had worth-while correction (over 20 degrees); they had had either pseudarthroses or short fusions. He noted that the follow-up was short; it should continue until the end of spinal growth for proper evaluation.

Dr. Paul E. McMaster [57] agreed that the need for such an osteotomy should be avoided by better preoperative correction and adequate postoperative fixation. He believed that the follow-up of the cases presented should be longer since five patients were followed for less than a year. Photographs of the patients would have been helpful to demonstrate cosmetic improvements.

Mold Arthroplasty and the Bony Ankylosed Hip. Dr. Morton Smith-Petersen [58] and Dr. Otto E. Aufranc [59] presented an analysis of the results of forty-one mold arthroplasties performed in twenty-eight patients with long-standing bony ankylosis of the hip as the result of surgery, infection, rheumatoid arthritis, or tuberculosis. The follow-up after arthroplasty ranged from one and one-half to twenty-six years.

Dr. Carroll B. Larson [59] discussed some of the many factors that influence the result after this type of surgery and stressed how difficult it is to determine what proportion of the result is due to the operation itself.

Dr. J. R. Schwartzmann [60] pointed out that arthrodesis of the hip in proper position is a satisfactory solution for many patients. He also remarked on the difficulty of evaluating the results of arthroplasty objectively.

A Method for Replacement of the Anterior Cruciate Ligament to the Knee. Dr. Don H. O'Donoghue [61] presented his method for the reconstruction of the anterior cruciate ligament of the knee. The iliotibial band is dissected out of the thigh, leaving its distal end attached. It is then threaded across the joint through drill holes in the tibia and femur so that the ligamentous portion of the tract, which normally extends from the lower part of the femur to the tibia, replaces the cruciate ligament. The defect thus formed on the lateral side of the knee is then repaired by plicating the less dense proximal portion of the tract across the joint. The surgical technique was illustrated by slides. The results of twenty-nine consecutive operations in athletes, most of them under eighteen, were analyzed, with follow-up ranging from one to four years. The results showed significant improvement in 75 per cent of the patients; none seemed any worse than before the surgery. The major complication was infection at the donor site (10 per cent), but none of the infections was disastrous. The operation was not presented as a substitute for the repair of the freshly ruptured

56. 2627 East Washington Street, Pasadena 8, California.
57. 435 North Roxbury Drive, Beverly Hills, California.
58. 266 Beacon Street, Boston 16, Massachusetts.
59. University of Iowa, Iowa City, Iowa.
60. 2415 East Adams, Tucson, Arizona.
61. 1111 North Lee Street, Oklahoma City 3, Oklahoma.

cruciate ligament. Participation in football following this reconstruction was discouraged. The author stated that this type of anterior-cruciate reconstruction has given more favorable results than any of the methods previously employed.

DR. DONALD B. SLOCUM [62] considered the indications for this operation and suggested that it should perhaps be limited to young athletes. Kaplan's studies show that the ligamentous portion of the tensor fasciae latae, the fibular collateral ligament, and the popliteus tendon all contribute to stability on the lateral aspect of the knee. Loss of only one of these permits the knee to operate without decrease of lateral stability. Because of this and because of anticipated functional hypertrophy of fascia, it is debatable whether the heavily plicated fascia used to fill the defect left by the removal of the ligamentous portion of the tensor fasciae latae is necessary.

DR. CARLO S. SCUDERI [63] congratulated the author on his results and confessed that in his own cases, reconstruction has always resulted in some permanent loss of knee flexion. Because of concurrently torn medial collateral ligaments of the knee, instability is frequently a serious problem in later years, and he reconstructs the medial collateral ligament after the anterior cruciate has been reconstituted.

62. 431 Eugene Medical Center, Eugene, Oregon.
63. 104 South Michigan Avenue, Chicago 3, Illinois.

WILLIAM AUGUSTUS BOYD

1881—1961

William Augustus Boyd was born in Charleston, South Carolina, on March 19, 1881, a member of a distinguished family. He was the son of the late Bernard and Joana W. Sherfasee Boyd. His early education was in the Charleston High School and the College of Charleston. His professional education was in the Philadelphia School of Anatomy and the University of Pennsylvania Medical School. After graduation from the University of Pennsylvania Medical School in June 1903, he served an internship in the Howard Hospital, Philadelphia, and was chief resident at the Philadelphia Orthopaedic Hospital. Following his hospital training, he began private practice in Columbia, South Carolina, September 1904, and continued to practice in Columbia until the time of his death, a period of continuous medical practice of fifty-seven years.

On February 14, 1906, he was married to Miss Mary Sweat Keller of Meinhard, Georgia, and from this union there was one daughter, Mary Keller Boyd. Both Mrs. Boyd and Mary Keller survive him.

During Dr. Boyd's period of practice, he obtained a period of great prominence in the field of orthopaedic surgery and held many positions of great trust and responsibility, as well as having many honors bestowed upon him. His vision, ambition, knowledge, and surgical skill led him to great attainments. In 1920, he organized the Cripple Children's Clinic at the Columbia Hospital, which eventually grew into the state-wide program of care for the crippled child. This remained his first love in his profession. Many times during the early phases of this program, there was great difficulty in obtaining funds for hospitalization and care of the crippled child. He had to appeal to the State Legislature and to the Governor of the State for the funds in order to keep the program alive.

He was interested not only in children's orthopaedic surgery, but also in adult orthopaedic surgery and in surgery of trauma. He was surgeon for the Seaboard Air Line Railroad, the Southern Railroad, and the Atlantic Coast Line Railroad. He became president of the medical organization of each of these three railway surgeons associations, a distinction that no other man has obtained.

Dr. Boyd was the author of many scientific papers which were published in various medical

journals. His basic ideas in orthopaedic surgery have stood the test of time and are still in practical use. He regularly attended the various scientific orthopaedic meetings and kept well abreast of all of the newer concepts in orthopaedic surgery.

He was a member of The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, a Diplomate of The American Board of Orthopaedic Surgery, a member of the Georgia and North Carolina Orthopaedic Associations, the Southern Surgical Association, the American Association of Railway Surgeons, a Fellow of the American College of Surgeons, as well as a member of many other scientific organizations.

Dr. Boyd's personal charm was one of his greatest attributes. All who had the privilege of knowing him loved him. His Chesterfieldian manner endeared him to his friends. He was the delight of any social gathering. As a raconteur, he was unsurpassed. He was the master of many dialects and pantomime. With his ability to relate stories, his acting ability, and his speaking ability, he thrilled thousands in his audience.

With his keen mind, he remained interested in things professional and social until the time of his death.

J. T. G., A. T. M., and W. C. C.

News Notes

The Part I examination of the **American Board of Orthopaedic Surgery** will be given on June 18 and 19, 1962, in Philadelphia, Pennsylvania, Nashville, Tennessee, and Palo Alto, California. The deadline for filing applications for Part I examination is January 1, 1962.

The **Australian and New Zealand Orthopaedic Associations** are holding a combined meeting at Wairakei, New Zealand, February 5 through 8, 1962. American orthopaedic surgeons who may wish to attend this meeting will be welcomed.

The Seventeenth Annual Meeting of the **American Society for Surgery of the Hand** will be held Friday and Saturday, January 26 and 27, 1962, at the Palmer House, Chicago, Illinois. The following program has been arranged:

Friday Morning

The Redistribution of Functional Units in Reconstructive Hand Surgery: J. William Littler, M.D., New York, N. Y.;

Neurovascular Island Pedicle Transfer Extension in Usage: William H. Frackelton M.D., Milwaukee, Wisconsin;

Resurfacing the Thumb Following Major Skin Loss: R. M. McFarlane M.D., London, Ontario, Canada, and W. B. Stromberg, M.D., Chicago, Illinois;

Late Results of Finger Tip Injuries: M. J. Sturman, M.D., and Robert J. Duran, M.D., Columbus, Ohio;

Local Filleted Pedicle Grafts—Their Use in Reconstruction of the Hand: Lee Milford, M.D., Memphis, Tennessee;

A Study of the Successes and the Failures in Extensive Hand Crush Injuries: K. H. Sponsel, M.D., Minneapolis, Minnesota;

Mallet Finger: H. H. Stark, M.D., Joseph H. Boyes, M.D., and James N. Wilson, M.D., Los Angeles California;

Athletic Injuries of the Hand and Digits: Donald R. Pratt, M.D., San Francisco, California;

Experimental and Clinical Transplantation of Autogenous Bones and Joints: Martin Entin, M.D., and Jack Alger, M.D., Montreal, Quebec, Canada.

Friday Afternoon

"Nerve Regeneration"—Its Principles and Practice: Paul Weiss, M.D., New York, N. Y.;

Some Studies on Restoration of Sensation in Hands with an Extensive Defect in the Median Nerve: Erle E. Peacock, Jr., M.D., Chapel Hill, North Carolina;

Carpal Tunnel Median Nerve Compression—268 Cases: Uberto Mangini, M.D., Florence, Italy;

Nerve Compression Syndrome in the Hand: H. Minor Nichols, M.D., Portland, Oregon;

Lipomas as a Causative Factor of Peripheral Nerve Palsies: William L. White, M.D., and D. C. Hanna, M.D., Pittsburgh, Pennsylvania;

The Electromyogram in Evaluating Upper Extremity Peripheral Nerve Lesions: J. Leonard Goldner, M.D., Frank Clippinger, M.D., and John Roberts, M.D., Durham, North Carolina;

An Electromyographic Study of Intrinsic-Extrinsic Interplay in the Normal, Moving Hand: Charles Long, M.D., Mary E. Brown, M.A., and Gerald Weiss, M.A., Cleveland, Ohio;

A New Technique for Correction of Clawed Fingers Due to Intrinsic Paralysis: E. Zancoli, M.D., Buenos Aires, Argentina;

Surgery of the Thumb in Rheumatoid Arthritis: M. L. Clayton, M.D., Denver, Colorado;

Arthroplasty of the Metacarpophalangeal Joint in Rheumatoid Arthritis: S. Benjamin Fowler, M.D., Nashville, Tennessee.

Saturday Morning

Tendon Grafting in the Less Than Optimum Situation: R. M. McCormack, M.D., Rochester, New York;

An Evaluation of the Healing Process Following the Application of an Artificial Tendon Sheath (Silastic) to Avian Tendon Autografts, Homografts, and Irradiated Homografts: Franklin Ashley, M.D., Leonard Marmor, M.D., Teodor Palak, M.D., and Robert S. Stone, M.D., Los Angeles, California;

Experimental Tendon Suture to Bone: R. J. Cowan, M.D., and A.D. Forward, M.D., Vancouver, British Columbia, Canada;

Restoration of Elbow Flexion by Transplantation of Sternocleidomastoid Muscle: Robert E. Carroll, M.D., New York, N. Y.;

Isolated Traumatic Dislocation of Distal Ulna: K. G. Heiple, M.D., A. A. Freehafer, M.D., Cleveland, Ohio, and A. Van't Hof, M.D., Grand Rapids, Michigan;

Small Blood Vessel Anastomosis for Salvage of Severely Injured Upper Extremities: Harold E. Kleinert, M.D., Louisville, Kentucky;

Small Blood Vessel Anastomosis: Utilization of a Microsurgical Technique: Philip H. Davis, M.D., and J. J. Jacobson, M.D., Burlington, Vermont;

The Hand as an Index to Systematic Disease: H. B. Brandburn, M.D., Robert Chase, M.D., and John Feisel, M.D., New Haven, Connecticut;

Giant-Cell Arteritis—An Acute Hand Problem: E. I. Bugg, M.D., and R. W. Coonrad, M.D., Durham, North Carolina;

Gangrene of the Extremities in the New Born: J. W. Smith, M.D., H. Conway, M.D., and G. Currarino, M.D., New York, N. Y.;

Ehlers-Danlos Syndrome and Its Relation to the Hand: Paul Wallace, M.D., St. Petersburg, Florida.

The Board of Administrators at Tulane University has established an endowed **Chair in Orthopaedic Surgery at Tulane University School of Medicine.** The Chair, to be known as the Lee C. Schlesinger Professorship, was made possible by a gift from the Harry Latter family memorializing the late Dr. Lee C. Schlesinger who served as associate Professor in Clinical Orthopaedics at Tulane University before his death. Dr. Jack Wickstrom, Professor and Chairman in the Division of Orthopaedic Surgery at Tulane, is the first incumbent.

Dr. Harold B. Boyd, Professor of Orthopaedic Surgery, University of Tennessee College of Medicine, will be the **Seventh Samuel Higby Camp Visiting Professor of Orthopaedic Surgery** at the University of California School of Medicine in San Francisco, March 5 through 16, 1962.

Columbia University College of Physicians and Surgeons is sponsoring a three-day Symposium entitled Basic Problems in Neoplastic Disease, March 12, 13, and 14, 1962. This Symposium will commemorate the Fiftieth Anniversary of the Institute of Cancer Research at Columbia University and the Tenth Anniversary of its affiliated facility, The Francis Delafield Hospital. The Symposium is open without fee to all interested workers. For details, including application to attend sessions, write to the Institute for Cancer Research, Columbia University College of Physicians and Surgeons, 630 West 168th Street, New York 32, N. Y.

MEDICO is increasing the number of medical and personnel serving in its overseas hospital and clinic installations. There are fifteen MEDICO-sponsored units in twelve countries. At present surgeons, internists, general practitioners, and anesthesia specialists are needed in Afghanistan, Cambodia, Vietnam, Malaya, Laos, and Haiti. Specific information will be sent on request to MEDICO, 420 Lexington Avenue, New York 17, N. Y.

The Annual Meeting of **The Georgia Orthopaedic Society** was held at the Cloister, Sea Island, Georgia, on September 30 and October 1. Dr. Fred E. Murphy was President, and Dr. J. S. Speed, Memphis, Tennessee, was the guest speaker. Officers for the ensuing year are Dr. F. James Funk, Jr., President, and Dr. Richard E. King, Secretary-Treasurer. The next Annual Meeting will be held at The Cloister, Sea Island, Georgia, September 28 and 29, 1962.

A **Postgraduate Course in Surgery of the Hand** will be given at Tulane University, New Orleans, Louisiana, under the direction of Dr. Daniel C. Riordan and Dr. Jack Wickstrom, March 22, 23, and 24, 1962. Dr. Adrian Flatt is to be guest lecturer.

The Sixth Annual Meeting of the **Pennsylvania Orthopedic Society** was held in Pittsburgh, Pennsylvania, October 20, under the Presidency of Dr. John J. Gartland.

Book Reviews

THE TRANSPLANTATION OF TISSUES AND ORGANS. Michael Woodruff. Springfield, Illinois, Charles C. Thomas, 1960. $25.50.

Readers of this Journal will find this book a bag full of assorted game, some of it choice, some of it unsuitable to their needs. The book is hard to characterize—it is not a textbook, not an up-to-date review; it concerns the whole field of tissue transplantation, as the title implies. It is a large volume, over 750 pages, more than 100 of which are bibliography. Perhaps the best part of the book is the first eight chapters (154 pages) which give an up-to-date summary of the biological techniques, observations, and implications of tissue transplantation, developments whose over-all significance has been symbolized by the recent Nobel Prize awards to Medawar and Burnet. The first quarter of the book will be most welcome to those not familiar with the massive recent literature on the immunological principles evolved through the study of homotransplantation, heterotransplantation, and so forth, using such experimental procedures as radiation, hormone administration, and conditioning through repetitive administration of tissue or tissue derivatives from the same or other animal species. This part of the book is indeed a masterful review and condensation of diverse biological observations which would seem to defy systematization. This part of the text puts into perspective the clinical observations and procedures which form the remaining three-quarters of the book.

The chapters entitled "Storage and Sterilization of Tissues" and "Transplantation as an Instrument of Research" concern such diverse topics as the survival of tissues, organs, and animals after freezing; the methodology of experimental embryology; and chemotherapy. Obviously, it is impossible for the author to delineate fully the relationship between transplantation experiments and those many fields in which it operates as a potent tool: genetics, embryology, physiology, immunology, and oncology, to name only a few. Yet, the author has included snatches of each of these subjects. Perhaps their inclusion may serve some useful purpose for laboratory neophytes who can refer to the bibliography for further reading or for clinicians who are interested in the ramifications of the transplantation process. For either reader, however, the details of methodology seem to be out of place, for although the author has epitomized well the numerous observations and opinions offered in these fields, the absence of a critical expression of his own opinions, where conflicting observations have been recorded, detracts somewhat from the presentation.

These criticisms also apply to the clinical part of the book. One would not consult this book for the details of procedure in doing a skin graft, a bone graft, a tendon transfer, or a corneal or kidney transplant, yet details of all of these procedures are included. The detail seems insufficient to guide the prospective surgeon and too much for the reader not concerned with technique.

The readers of this Journal will find special interest in the chapters on transplantation of bone, cartilage, and tendon. The chapter on bone, the only one written in collaboration, is a fair statement of the present evidence but includes a number of peripheral subjects. Thus, the authors place in the same chapter data concerning the ultrastructure of bone and its mineral phase, on the one hand, and on the other, illustrated procedures on how to do a spine fusion with an H graft or a Brittain hip fusion. If such encyclopedic coverage were to be done adequately, the book would have to be many times its present size. Despite the diffuseness of this volume, one gains a great deal from reading it. Scarcely anyone will go through each individual chapter on the transplantation of separate tissues. But nearly everyone will find much of value in many sections of the book, particularly the first part and the part which deals with his particular specialty. This book is well written, clear, and profusely illustrated and is well worth reading. The bibliography is magnificent; as a summary of some of the recent work, it indicates well where the best reviews of subjects can be found and thus serves as an excellent starting point for reading on specific subjects.

Jonathan Cohen, M.D.

COMPLICATIONS IN SURGERY AND THEIR MANAGEMENT. Edited by Curtis P. Artz, M.D., and James D. Hardy, M.D. Philadelphia, W. B. Saunders Co., 1960. $23.00.

A good surgeon learns from his every mistake; the best surgeon learns from the mistakes of others. Study of this volume, written by authors expert in each field, is the opportunity for the surgeon to avoid the pitfalls and complications so constantly a part of surgery. The possible complications of surgery in general, as well as those common to particular procedures, is discussed from the standpoint of pathophysiology, prophylaxis, and treatment.

Up-to-date discussions of current factors in the development of infections and their proper antibiotic management bring order out of the massive literature on the subject. Wound healing, shock therapy, and management of wound complications and fluid balance are well discussed.

Experts in fields of special interest describe the practical management and prophylaxis of such dreaded complications as renal, cardiac, and hepatic failures.

One may refresh his knowledge of problems in anesthesia or problems following x-ray therapy by investigating chapters on these subjects written by experienced specialists.

The possibilities of complications associated with each regional surgical exercise are discussed under separate headings for quick reference by the surgeon before embarking on a particular surgical procedure.

Complications in Surgery and Their Management should be readily available to every surgeon both for his general perusal and for a specific reference.

Robert A. Chase, M.D.

CHIRURGIE DU RACHIS. André Sicard. Monographies Chirurgicales (Collection Henri Mondor). Paris, Masson et Cie, 1959. 6,000 fr.

The monograph on the surgery of the spine is one of intended eighteen volumes of a collection of monographs under the general editorship of H. Mondor. It apparently reflects the personal experience of the author, Sicard, based on the observations of many patients, 3,000 of whom were operated on for conditions of the spine. It is remarkable to see the extent of material covered in this book of 473 pages; it is truly encyclopedic in its contents. The first part of about 100 pages describes the operative procedures which are performed on the spine. Although briefly, more than the essential methods on the cervical, thoracic, lumbar, and sacral spine are given.

The other chapters include traumatic affliction of various parts of the spinal column, the painful spine, sciatic radiation, neuralgias of the lower extremity, spinal deviations, congenital malformations, spondylolisthesis, tuberculous and non-tuberculous spondylitis, tumors of the spine, vertebral edinococcus, and osseous dystrophies.

Some of the chapters are perhaps too brief, but are of value inasmuch as they reflect the author's experience stated succinctly and clearly. Although the author states that numerous publications on the matter are too extensive to allow a "bibliography assuming the proportions of a monument of erudition", it is regrettable that the bibliography is omitted. The volume is of interest as an account of valuable personal experiences on multiple afflictions of the spinal column.

Emanuel Kaplan, M.D.

PATHOLOGIC PHYSIOLOGY. MECHANISMS OF DISEASE. Edited by William A. Sodeman, M.D., Sc.D., F.A.C.P. Philadelphia, W. B. Saunders Co., 1961. $15.00.

The professed purpose of this book is admirable—to bridge the gap between standard textbooks of physiology and medicine by "presenting a clinical picture of disease seen as physiologic dysfunction". However, the section devoted to the locomotor system, which should be of special interest to the readers of this Journal, not only fails in its purpose, but can be considered another sign of the general disregard or even disdain for orthopaedics so manifest in most undergraduate curricula. Those engaged in academic teaching have long been aware of the inadequacies of undergraduate medical courses in anatomy and pathology for the training of orthopaedic surgeons and also for general practitioners who will examine and treat patients with lesions or dysfunction of the locomotor apparatus. This book carries on the customary underemphasis and gives no more than a nod to the existence of locomotor problems. The entire section on the locomotor system consists of thirty-two pages in a book of over a thousand pages. Ten lines dispose of the diseases of muscle, and nine lines, those of bone. The section on joints is occupied nearly exclusively with arthritis, and references to pathology and physiology are narrowly selected for their pertinence to the rheumatologists' concerns. Thus, the anatomical and mechanical aspects of the articular components are referred to in summary fashion, omitting all detail, so as to give space to newer chemical data, without specifying their pertinence or indicating the imprecision of the generalizations suggested: for example, "fibers of collagen are denatured by polysaccharide".

The remainder of the book will certainly be a welcome reference for medical students who would like to correlate better their anatomical, pathological, and normal physiological knowledge. Since the emphasis is primarily on the diseases of internal medicine, the thoracic and abdominal viscera are treated in much more complete fashion than, say, the nervous system. Since different authors are responsible for the various chapters, there is some unevenness in the merit of individual chapters, but this is to be expected. The gross injustice done to the locomotor apparatus, however, should alert those in orthopaedic academic circles to the need for proper representation not only in the undergraduate curriculum, but also in the fashioning of textbooks designed for undergraduate consumption. Perhaps succeeding editions of this text may correct this bias and certainly the editor should be urged to do so.

Jonathan Cohen, M.D.

ACTUALITÉS DE CHIRURGIE ORTHOPÉDIQUE ET RÉPARATRICE: Professor R. Merle d'Aubigné, Cochin Hospital, Paris. Clinique Chirurgicale Orthopédique et Réparatrice. Paris, L'Expansion Scientifique Française, 1958–1959.

This volume represents three forums on traumatology held at the Cochin Hospital under the direction of Prof. Merle d'Aubigné.

The first is on the problem of open fractures of the lower extremity, the second on fractures of both bones of the forearm, and the third on traumatic lesions of the cervical spine.

The forums are held four or five times every year at the Cochin Hospital. They represent different problems of orthopaedic surgery and traumatology with participation of surgeons, French and foreign, of different special and related fields. It permits free exchange of ideas and free discussion with a general and especially practical orientation.

The first forum on open fractures of the lower extremity covers a vast experience by five prominent surgeons who treated a large number of open fractures. The reports are short and practical. Each surgeon ends his report with a resumé enumerating the basic principles of his treatment. Open reduction with osteosynthesis is advised in special cases with thorough coverage of bone and adequate immobilization in specially organized hospitals.

The second forum on fractures of both bones of the forearm presents the viewpoints of the protagonists of closed and open reduction with and without osteosynthesis. The results obtained by widely known surgeons using these methods are reported.

The third forum is dedicated to treatment of the cervical spine in well directed centers where all necessary treatment can be efficiently applied.

It is remarkable how much valuable material is contained in the eighty-six pages of this preeminently practical and well illustrated publication.

Emanuel Kaplan, M.D.

CALCIUM METABOLISM AND THE BONE. L. P. R. Fourman. Springfield, Illinois, Charles C. Thomas, 1961. $8.50.

Those concerned primarily with the surgical aspects of the skeletal system have experienced a good deal of confusion in studying its metabolic problems. In recent years, the multidisciplinary approaches of symposia and conferences dealing with the skeleton have brought into prominence much new knowledge in the field, but in the process, the orthopaedic specialist has had to absorb much data, often with conflicting interpretations, on topics somewhat foreign to his usual conception of bone as a tissue. Some examples are the action on the skeleton of vitamin D, parathormone, the kidney, and the physiology of osteoporosis.

This small volume, about 200 pages of text and about 100 of bibliography, will be of great value to those who want a clear recital of the clinical and related experimental facts on these confused and diverse but interrelated subjects. While numerous reviews exist of several of the factors considered in this volume, there is no single source, to my knowledge, where one can easily find a recent summary of nearly all the material relating to bone disease and the role of the skeleton as a participant in the metabolism of calcium.

The emphasis in the book is on bone disease. The introduction (forty pages) sets the stage by summarizing normal calcium metabolism and this summary is especially worthwhile for its incorporation of much data; for example, the chemical components of the skeleton and the amount of calcium usually absorbed and excreted, which are difficult to find in more detailed studies where they are often obscured by the reported minor variations. In the principal section of the book, the author presents an analysis of the metabolic diseases of bone. First, he discusses hypocalcemia, hypercalcemia, nephrocalcinosis, and renal stones as factors in a number of diseases. He gives the signs, symptoms, and treatment and the laboratory investigations which will lead to a diagnosis in most cases. His principal topics are: osteoporosis, vitamin D and the diseases in which it is implicated, hyperparathyroidism and hypoparathyroidism; but he also discusses several other diseases where calcium metabolism is so disturbed that skeletal changes may be seen. Examples of these (sarcoid, steatorrhea, and thyroid disease) are covered in enough detail to afford a judicious understanding of the differential diagnosis but without encumbering the book with unrelated detail. A final section (forty pages) is devoted to the diseases of the kidney which have skeletal repercussions.

One feature of the book is the massive bibliography, references to which are used to portray areas of controversial data or interpretation. This allows a rather simple presentation of much that is ordinarily quite confusing. While the book lacks illustration, both roentgenographic and histologic, the text covers this deficiency rather well, and, as the author intimates, this material is not only bulky and extensive, but rather easily available in the literature. Altogether, the book can be highly recommended to students and those in training. For experienced orthopaedists it should be required reading.

Jonathan Cohen, M.D.

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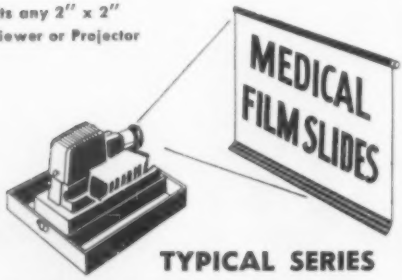

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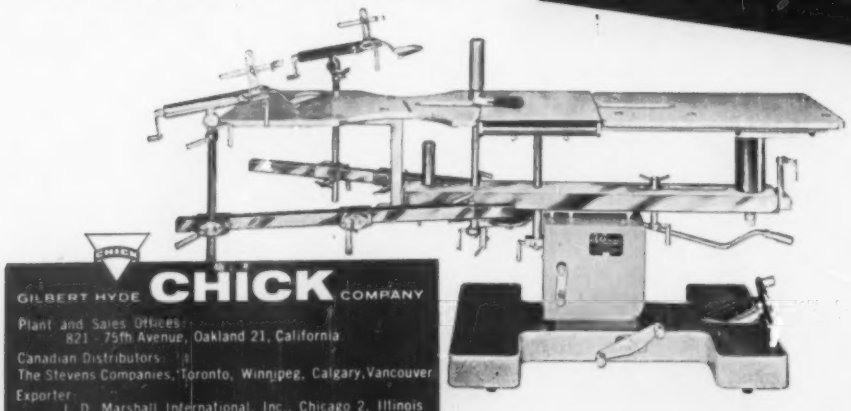

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